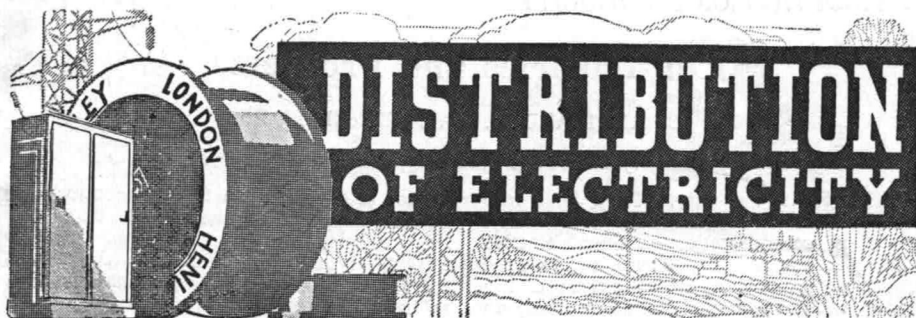




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Editorial

Youth Education

In our January, 1943, issue we referred to the inaugural *Conversazione* marking completion of the first term of the Henley Youth Education Scheme. The Henley Student Manual has now been compiled. This booklet, a copy of which is handed to every boy entering the service of W. T. Henley's Telegraph Works Co. Ltd., explains how the scheme was launched in 1942, and at the inaugural General Meeting, Sir Montague Hughman, the Chairman of the Henley Organisation, spoke of the wonderful oppor-

tunities available to all boys who take advantage of the educational facilities provided by the Company. He mentioned to the work done by Dr. P. Dunsheath, Director and Chief Engineer of the Company, who, as Chairman of the Education Committee has been largely responsible for the success of the scheme.

Every boy is given the option of undertaking a course of training extending over a period of years. On a selected day each week, boys who have shown that they can benefit from such privileges and have been accepted for the course, are released entirely from their normal duties with the Company in order that they may attend approved classes at selected educational institutions near to their place of employment. They are expected to devote themselves whole-heartedly to the courses laid down for them during this day and to attend a recognised educational establishment of their own choosing at least one other evening in the week, for which purpose, wherever practicable, they will be released from shift-work or overtime. In addition, they must undertake to carry out the homework in connection with their day course to the satisfaction of the Education Authorities.

The subjects selected for the day periods are of a more serious and fundamental nature, but a good deal of freedom is given in the selection of subjects for the evening courses. Boys are paid for time spent at the day establishment, and all fees, both for the day and evening courses, are paid by Henley's.

The scheme is not only intended to produce better workmen, better foremen, better managers, but also better citizens, and in addition to every encouragement being given to the boys to enlarge their mental outlook, physical training classes form an important part of the scheme.

On Theories and Problems

By REGINALD O. KAPP, B.Sc. M.I.E.E.

Pender Professor of Electrical Engineering, University College, London.

THEORIES are easy. They float into consciousness at all times of the day. They are an excellent pastime for active minds. But what is not so easy is to take the proper precautions so as to ensure that a theory shall be sound. I think that, in particular, two precautions are often neglected. One is to test the theory by the right criterion, the other properly to formulate the questions that are relevant to the subject under consideration. The first precaution has to be taken after and the second long before any theory has been formulated. Let each be considered in turn.

To find the right criterion with which to test a theory calls for much hard work; for a critical, penetrating, fluid intellect; for a cold, dispassionate willingness to face facts; for all the austerities of science, austerities as severe as those of ethics. The criterion of truth is, indeed, a hard taskmaster, exacting, uncompromising and inexorable. But how few can bear to submit to this taskmaster. Scientists do so, of course, so long as they are working in their own fields of study. But the rest of mankind will follow any form of asceticism more willingly than that demanded by science. The best of us are somewhat impatient of reason; we cannot easily overcome our distaste for hard, bare facts. So the criterion of truth, the only criterion allowed in scientific method, is rarely our touchstone. Human nature being what it is, we prefer the criterion of attractiveness: we test a theory for the beauty we find in it, the ideals it seems to foster, the comfort it brings us, the support it gives to our self esteem; not often enough for its compatibility with facts and logic.

If these rival criteria place us on the horns of a dilemma, we try to wriggle off by asserting that what is not good cannot be true; and we constitute ourselves the sole judges of what is good, meaning by the word that that appeals to us. By this subterfuge we make it appear that the criteria of truth and attractiveness are one. Hence a theory that seems, at a superficial glance, to conform to a preconceived notion of beauty or morals will be accepted readily, while one that an indolent mind cannot fit into its own private picture of an ideal world will be rejected with an equal lack of serious thought.

So it has been at all times in the world's history. The Copernican system, evolution, the psychology of Freud, have all been rejected in their day by criteria that have no meaning in science. These theories did not

appear attractive when first propounded, so others were preferred, theories that demanded less mental effort, that conformed better to the moral notions dominant in their time, that did not shake the vanity of mankind. It is true that in their day these unpopular theories were not called unattractive; men preferred to call them unmoral. But looking back we are now able to judge between the two epithets and we can see that the unmorality was fictitious, the unattractiveness sometimes real.

Admittedly, in well-cultivated fields of study, scientific discipline always prevails in the end; true theories are preserved and false ones fade out. It is more often in one of the misty, semi-philosophical no-man's lands that border several recognised fields and belong to none that all theories are allowed to flourish side by side, so that each visitor may choose according to his fancy. Hence all the "isms" that are to be found in such a no-man's land, the din of many voices, through which that of science is to be heard but faintly. It is assumed all too readily in a no-man's land that the first qualification of an arbiter is that he shall be a person with the right kind of ideals. The verdict of such a one will be accepted by all those whose ideals are similar and rejected by all those whose ideals are different. In such a place loyalties largely govern a person's adherence to a doctrine, so that one need only know to what profession he belongs in order to guess which theory he favours. It is in regions where conflicting theories are most noisily defended that one may meet people so sure of themselves that they deny the very existence of a problem. "There is no question any more. Any doubts have been disposed of long ago," they will assert.

Often, it cannot be denied, each of two opposed theories will be supported with evidence that has been collected without bias, by the cold, clear light of science. And yet one of the theories must be wrong. Such strictly scientific facts would certainly suffice to weed out all false theories, were it not for neglect of the second precaution that has been mentioned above; the precaution of properly formulating the questions that are relevant to the discussion.

For to be of value as evidence, facts must not only be correct; they must also be relevant. And to be relevant they must come as answers to relevant questions. Hence, after formulating the problem itself, the next

step in any scientific enquiry is to find the questions that are relevant and to word them properly. This task must continue for a long while before any theories are formed. A scientist is forever asking questions. The problems that interest him, the little things that catch his observant eye, cause him to form questions beginning with why, how, when, where, how much. The general public thinks of the scientist as one who knows. Were they to think of him as one who asks, they would create a more correct and let it be added, a more appreciative picture. Most of the scientist's questions are mere commonplace routine. But their dullness does not make them insignificant. Others are arresting, provocative, disturbing; they raise doubts; they call for hard thinking; they may condemn the questioner to years of painstaking research; they may challenge his cherished convictions; they may destroy the work of a lifetime. Some questions cast their fierce light into a corner of the questioner's mind that he had thought clean and tidy, and reveal the litter there, the confusion, the dust and the cobwebs.

If this part of a scientist's work is sometimes painful to himself, it is also sometimes unpopular with others, as Socrates learnt to his cost. So such work is rather out of place in the misty no-man's lands referred to. But within his own domain a scientist may ask his questions without fear of paining anyone but himself. And he does ask them all: the dull ones, the insistent ones, the awkward ones, without shrinking from the consequences. He does not always succeed, for he is not infallible. Indeed, much of the story of scientific endeavour is the story of the search for the relevant question. Until this has been found, facts are marshalled and studied that contribute nothing to a solution of the problem, while those that might help are overlooked. But once the right question has been found and properly worded there is no more fumbling, no more missing the point, no more obscure reasoning and unhappy argument.

Some of the world's greatest discoveries illustrate aptly what the appropriate question can do. Not infrequently it took form in a moment of inspiration. "Why did that apple fall?" asked Newton. "What has the apple in common with other objects that follow predictable paths, with comets, for instance?" He asked some other questions at the same time, of course. I am oversimplifying. But could I present all the thoughts that must have combined to puzzle Newton as the principle of gravitation was developing in his mind, it would show only the more fully how in science asking and discovering are the two parts of one process. "How many seconds does that lamp take to swing to and fro?" asked Galileo as he sat in

church one day. "Will each journey take more or less time as the lamp slows down and the journeys become shorter?" Using his pulse as a stop watch he discovered that the period of swing was independent of the amplitude. This led him to ask the further question, what the period of swing does depend on, and so, by means of question and answer, Galileo arrived at the law of the pendulum. "If electricity can produce magnetism, as Oersted and Ampere have shown, can magnetism not also produce electricity?" asked Faraday. He continued to ask it for years and carried in his waistcoat pocket a small magnet wrapped with wire, at which he would gaze from time to time as he pondered on this question. At last he found the answer, and with it the electric dynamo was born. "Why can a wireless signal be received from a station far below the horizon, from which the signal from a searchlight would be out of sight? Both signals consist of electro-magnetic waves. Why do they behave differently?" asked several people. Heaviside found part of the answer. He suggested that a layer of rarified air high up in the sky acts as a mirror to long wireless waves and is transparent to the short ones from a searchlight. Thus he discovered what is now known as the Heaviside layer. "Why does the hull of a ship disappear first and the mast later as the ship sails away across the horizon?" anyone might have asked in ancient times when men still believed in a flat earth. But no one did ask, and so no one discovered that the earth is round. In those days men lacked the scientist's divine curiosity. Human nature has not changed very greatly since then, some of us still lack this divine curiosity all the time and all of us lack it some of the time.

When a scientist has asked the right question he has not yet made a discovery. But he has often taken the longest and most difficult step towards one. In the examples given, other scientists, if they had overheard the questions and (a most important condition) if they had appreciated their significance, could have found the correct answers. Many of us understand how to find knowledge; but only a Galileo, a Newton, a Faraday knows how to seek it.

E.I.B.A. Collection

W. A. Dutton (Cawnpore) £1 1s. 0d.; W. H. Lythgoe £1 1s. 0d.; J. M. Faulkes (Bedford) 5s. 0d.; H. Smith (Manchester) 5s. 0d.; F. W. M. Anderson £1 1s. 0d.; W. M. Baxter 5s. 0d.; W. McCausland (Bournemouth and Poole E.S. Co.) 4s. 10d.; F. Smythe 5s. 0d.; Sale of Calendars 5s. 0d.; Total £4 12s. 6d. Total to date for 1943 £104 0s. 0d.

*Synthetic Rubbers and Plastics

III. (Part 2)—Thermoplastics for Cables

By W. F. O. POLLETT, M.Sc., A.I.C. and F. G. R. JESSON, B.Sc.

Henley Research Laboratories

THE first hydrocarbon polymer of the non-polar type to receive attention was polystyrene, known commercially as Distrene, Trolitul, and Victron, which is derived from monomeric styrene. Monomeric styrene occurs in small amounts in hydrocarbons obtained by the cracking or heat treatment of petroleum products but the usual method of manufacture involves the replacement of a hydrogen atom in ethyl benzene by a chlorine atom. The resultant compound is then converted into styrene by passage of the vapours through a hot tube at about 1,000° F. In this respect styrene is of considerable interest since it can be manufactured entirely from home-produced materials, i.e. coal and hydrochloric acid. The monomer is a colourless liquid of penetrating odour having a boiling point of 290° F. and from the constitution expressed diagrammatically in Fig. 1 it will be seen that the typical vinyl group found in polyvinylchloride is attached to a benzene ring.

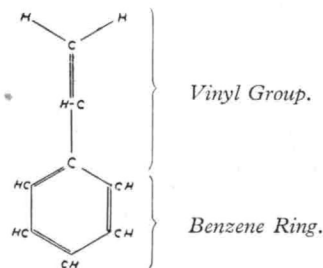


FIG. 1. Monostyrene.

Polymerisation can be effected by various agents such as heat, light and certain chemicals. The polymer is built up as shown in Fig. 2.

Thus a long zig-zag hydrocarbon chain with the hexagonal benzene rings at the side is built up. The complete saturation of the chain and the stable nature of the benzene ring ensure that polystyrene is extremely inert and the chemical changes which occur in the case of unsaturated hydrocarbons such as rubber are impossible.

As already stated, polymerisation can be brought about by various means. Moreover, the process can be controlled so as to keep the length of the chain within certain limits, and polymers having varying numbers of carbon atoms in the chain are available. In general, it can be stated that rapid and irregular polymerisation gives rise to short-chained polymers having a tendency towards secondary polymerisation which leads to shrinkage and the setting up of internal stresses, resulting finally in "crazing"—a phenomenon frequently met with in the earlier varieties of polystyrene. The physical and electrical characteristics of polystyrene are contained in Table II.

TABLE II.

Physical and Electrical Characteristics of Polystyrene.

Specific gravity	...	1.05—1.06
Brinell hardness	...	20—30
Refractive index	...	1.668
Water absorption (%)	...	Nil to 0.02
Tensile strength (lbs./sq. in.)	...	6,000—7,000
Specific dielectric resistance at 20° C. (ohms/cm. ³)	...	1 × 10 ¹⁸
Specific inductive capacity	50 cycles to 0.75 megacycles at 80% R.H.	2.4—2.6
Power factor	and 20° C.	0.0002—0.0003
Breakdown voltage (volts/mil)	...	12,000

At ordinary temperatures polystyrene is a rigid and glass-like material, although when heated to about 180° F. it becomes distinctly elastic and rubbery in nature. In fact, the only physical difference between rubber and polystyrene is that at ordinary temperatures rubber remains soft and highly elastic whilst polystyrene is in a congealed state. The same condition does not arise with rubber until temperatures in the region of —112° F. are reached. At the temperature at which polystyrene becomes rubbery in nature it can be moulded and extruded, and these processes have been adopted for the production of rigid

*Continued from July, 1943 issue of *Distribution*

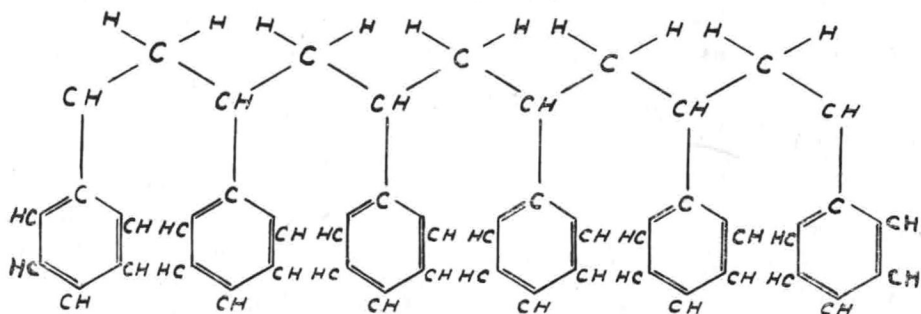


FIG. 2. Polystyrene.

domestic articles having a highly attractive appearance and for mouldings such as insulators employed for electrical purposes. No plasticiser has yet been found which provides satisfactory physical properties over the normal working range. It is, however, possible to develop a fairly high degree of flexibility in polystyrene when in the form of relatively thin films and threads, by a mechanical process in which the molecules are aligned by subjecting the material to a stretching process. This is effected commercially by extrusion in the desired form followed by stretching whilst still in the plastic state. By this means polystyrene known under the trade name of Styroflex can be prepared as flexible threads and tape suitable for use in the manufacture of insulated cables, and has been extensively used for transmission systems operating at high frequencies.

A further application of polystyrene has been in connection with the jointing of super tension cables. This method, which has been the subject of several patents, comprises the injection of monostyrene into the joint followed by the application of heat to effect polymerisation in situ. In other patents it has also been proposed to employ, as an insulant for high frequency cables, a compound formed by heating rubber swollen in styrene, whereby the styrene becomes polymerised.

Some indication has already been given in previous articles of the important relationship between the petroleum industry and the synthetic rubber-like materials. Petroleum consists of a mixture of hydrocarbons. During recent years considerable attention has been paid to increasing the yield of the more desirable fractions in crude petroleum by a process known as cracking, in which the more complex bodies are converted by heat treatment into simpler hydrocarbons of higher volatility. During this operation large quantities of gaseous products consisting mainly of ethylene, propylene, and

isobutylene are formed and by suitable methods it is possible to separate these olefines, as they are collectively termed by the chemist, into their separate components. These olefines form the basis of many of the synthetic rubbers and thermoplastics and it is now proposed to discuss polyisobutylene and polythene, both of which are thermoplastic hydrocarbon polymers derived from this class of bodies.

Polymerisation of isobutylene is carried out at a low temperature in the region of 14° F. in the presence of traces of a material such as boron fluoride, which acts as a catalyst or accelerator of the reaction. The process has formed the subject of many patents, and polymers are available under the trade names of Isolene, Vistanex and Oppanol. The polymers are colourless materials, the lower ones being viscous fluids, and the higher polymers closely resemble rubber, both in their physical characteristics and in the fact that they are essentially pure hydrocarbons of relatively long chain length having a regular distribution of short side substituents. The most characteristic difference lies in the fact that rubber, as already shown in the previous article, still remains unsaturated and is therefore capable of vulcanisation, whilst polyisobutylene is fully saturated and cannot be vulcanised. Mechanical working of the material on a rubber mill causes an increase in plasticity in the same way as it does with raw rubber, and extremely large amounts of filler may be incorporated into polyisobutylene without materially affecting its flexibility. The physical and electrical characteristics of a polymer having an average chain length of 7,000 carbon atoms is shown in Table III.

Polyisobutylene is unaffected by water and is also highly resistant to ozone, acids and alkalis. It is either swollen or dissolved by most organic solvents.

In view of the highly rubbery nature of polyisobutylene it might be expected that it would find numerous applications for purposes

TABLE III.

Physical and Electrical Characteristics of Polyisobutylene, having an average of 7,000 carbon atoms in the chain.

Specific gravity	...	...	0.93
Tensile strength (lbs./sq.in.)	...	...	1,200
Elongation at break (%)	...	...	1,000
Specific idelectric resistance at 20° C. (ohms/cm. ³)	...	...	1×10^{15}
Specific inductive capacity	800 cycles, 80% R.H. and	...	2.3
Power factor	20° C.	...	0.0004
Breakdown voltage (volts/mil)	...	...	575

where rubber has been formerly used, but its use has been greatly restricted by reason of the fact that it shows a marked tendency towards flowing, even at ordinary temperatures. Perhaps one of its most important uses at present is as a plasticiser for polythene.

Polythene is the name given to polymers of ethylene discovered and developed by I.C.I. Ltd., and sold under the trade name of Alkathene. Polymerisation of ethylene is brought about by heating ethylene under high pressures of the order of 500 to 1,000 atmospheres in the presence of traces of oxygen. The length of the polymer chain can be controlled by changes in the oxygen concentration, pressure and temperature. In contrast to the rubber-like polyisobutylene in which carbon and hydrogen atoms are believed to take up a random configuration, due to free rotation at the carbon to carbon linkages, polythene assumes a closely packed symmetrical form leading to a tough and horn-like crystalline material, which is wax-like in appearance at ordinary temperatures. Polythene is, in fact, in many respects similar to gutta percha but with a considerably higher softening point. Its physical and electrical characteristics are shown in Table IV.

Polythene is practically insoluble in all organic solvents when cold, although it is readily soluble in most hot solvents. It is entirely unaffected by immersion in water and is highly resistant to acids and alkalis. Polythene is also of interest since, unlike other thermoplastics, it possesses a relatively sharp melting point in the region of 230°—250° F. At this temperature, however, it tends to oxidise in air with a marked lowering of the power factor and for this reason it is inadvisable to leave molten polythene in contact with air for prolonged periods.

TABLE IV.

Physical and Electrical Characteristics of Polythene.

Specific gravity	...	...	0.92—0.94
Tensile strength (lbs./sq.in.)	...	...	5,000—14,000
Elongation at break (%)	...	...	200
Brinell hardness	...	...	2
Refractive index	...	...	1.52
Specific dielectric resistance at 20° C. (ohms/cm. ³)	...	...	1×10^{17}
Specific inductance capacity	at 20° C.	...	2.3
	50 to	...	
	5×10^7 cycles	...	
Power factor	75% R.H.	...	0.0004
Breakdown voltage (volts/mil)	...	...	1,000

Although not possessing the elasticity of rubber, polythene is remarkably flexible and being thermoplastic in nature it can be readily shaped by moulding or extrusion. Because of the readiness with which it can be worked in the plastic state, combined with its extremely low power factor, it is an ideal insulant for high frequency cables. As already mentioned, it is usually plasticised with about 10% polyisobutylene in order to improve its flexibility at low temperatures. Plasticisation is usually carried out in an internal mixer or on open mixing rolls and the compound is then extruded on to a conductor. The extrusion machines employed for this purpose are exactly similar in principle to those used for rubber extrusion but the temperatures employed are rather higher because of the higher softening point of polythene.

While, in a general way, the technique which has been developed over a period of years for the production of rubber cables is applicable to synthetic thermoplastics, there are numerous differences in properties which have necessitated adjustment of factory methods. Synthetic thermoplastics, being initially in a relatively tough condition instead of having this state developed by subsequent vulcanisation, require much higher processing temperatures and are less amenable to cold fabrication. To solve the many problems resulting from the differences in behaviour has called for much investigation, but by co-operative effort of the industry as a whole in this country, considerable success has been achieved.

Answer to the "Savings" problem in the Problem Circle of this issue is:—Willie's surname is Brown. He has saved 1/6.

How Real are Post-War Bogeys?

By A. G. H. DENT, A.M.I.E.E., F.R.Econ.S.

THESE seem to be two main currents of thought about the post-war world—positive and negative. The negative thinkers apparently derive their lack of inspiration from various fears, taking different forms. There is the fear of national impoverishment because of the high cost of the war; the fear of accumulating national debt; of unemployment; of new and radical currents of thought—fear of change itself in all directions; of new ideas and of the unknown future.

In opposition to this group are those who see in the present difficult period of stress, great opportunities for constructive change. They do not fear impoverishment and they welcome the impact of new ideas upon a system of living which needs overhaul and repair.

The conflict between these two opposing sets of ideas is important because its outcome determines the course of events to come. There is an old Buddhist saying, "The future does not come from before to meet us; it comes streaming up from behind over our heads!" We have to work in both planes. Confidence in our capacity to solve the problems of the future is one key to their solution. Study and factual analysis of these problems is another key.

Some of them are confused by traditional habits of thought and by fear of the unknown future. There are various "bogeys" to examine. How real are they? What is their importance? It may be worth while analysing a few of the familiar bogeys—the great cost of the war and its danger of national impoverishment; the piling up of National Debt; Budget deficits; and the high cost of social insurance schemes.

These are a few out of a long list which will include other dismal matters such as the loss of foreign investments, the dangers of inflation and the difficult position of export trade. Let us take the first group to find out, within an all-too-brief study, whether we ought to be afraid of them or merely contemplate them as problems capable of solution.

In doing this we may recall the fact that production is wealth and is not to be confused with the tokens through which wealth is exchanged. If we turn back to the period following the last war, we find that this fact was ignored. The fearful orthodoxy of the 1920's produced a series of economy committees whose main idea seemed to be cutting down any expenditure capable of employing more people! Most people's recollections

of the Cunliffe Committee of 1919, the Geddes Committee of 1922 and the later May Committee will bear this out. There was a kind of financial hocus-pocus which prevented reconstruction projects. It is most unlikely that the same kind of mistakes will be made after this war but since, here and there, requests are heard to return 'to the normal'—whatever that means—we should examine the present problems factually. What about the cost of the war?

The Cost of the War

The cost of the war has to be considered in several aspects: in terms of human life; in destruction and depreciation of wealth-producing assets; in diversion of labour from constructive work to war materials; in years of lost training, and in monetary cost.

Taking the last item first, there has been a transfer of purchasing power; the bulk of Government spending has replaced the normal expenditure of private citizens. Roughly, £5,000 million were spent by the Government last year. About half this sum was collected from the citizens in the form of taxation; the other half they lent as savings for the use of the country. The extent to which the citizens have changed their spending and saving habits is shown by comparing the figures of 1942 with those of 1938. In 1942 the proportion of the national income derived from taxation had risen to 38% compared with 24% in 1938; the volume of consumption had decreased by 18% (about £700 million); and gross personal savings were about 5½ times the 1938 figure!

Naturally, in peace-time we should spend far more on personal needs; we would save less and we would pay less in taxes. A useful guide to the extent to which we are holding-off consumption in order to help to finance the war's requirements is shown in a recent study* by J. L. Nicholson. He has calculated index figures of consumption in terms of volume, for the main classes of normal expenditure. Taking the year 1938 as 100, the relative index figures for 1942 are: clothing, 58; food, 86; fuel and light, 96; rent, 101; drink and tobacco, 103; others, 69; total, 82.

In order to get these results and to finance the war, forms of State control and regulation have been essential, especially in the direction of freedom to spend. But the ration book and

* *Some New Estimates of Consumption*, by J. L. Nicholson, Institute of Statistics, Oxford, Bulletin Vol. 5, July 17, 1943. No. 10.

the coupon have been reasonably effective and have had an important influence in equalising purchasing power for necessities. If cost to the individual has been high in terms of taxation, it has been controlled as far as inflation is concerned. The Ministry of Labour cost of living index stands now at 113 (1924 average = 100) compared with 89 for the 1938 average. The index of average weekly wages stands at 142 compared with 104 for the 1938 average.

Costs have been high in terms of sacrifices of many things which we would have had in peace-time, particularly those things which raise the standard of living—new housing, schools and technical colleges. We make do with old clothes and battered furniture, with skeleton stair-carpet and blistered window sills. But we do not seem to mind very much about these more personal sacrifices.

The cost in war damage to buildings is a large item and it means that during the first post-war year when we should be building new houses on an enormous scale, we shall have to postpone part of this work in favour of a large, national repair campaign. Damage to factories has been less than might have been expected. Probably, a greater intrinsic loss has been the depreciation of much productive equipment, including transport, which has to put up with old stocks and a reduced efficiency of working. In the power field damage has been moderate, and national power resources have sustained a high level of productive efficiency and service to manufacturing and other industries.

To offset depreciation of wealth-producing assets there is the creation of many manufacturing plants of the most modern and efficient type which are capable of being used in peace-time for the production of much-needed commodities. To offset lost training in many trades there is the highly developed training of many branches of the fighting Services. In addition, industry has acquired a new source of skill among thousands of women workers.

If we look at the plus and the minus side of the war costs, there is no evidence to suggest that our resources and capacity to produce wealth should be less effective after the war than before it. The technique of production has advanced appreciably during war-time and productivity per man-hour is increasing. One of the most important factors affecting this productivity is that of labour relations, particularly labour co-operation. The growth and experience of Joint Production Consultative and Advisory Committees in industry should have a valuable influence on the industrial efficiency of the future.

The National Debt

Returning to the financial consequences of the war, what does the National Debt signify and how alarmed ought we to be about it?

Confusion usually arises from drawing false analogies between individual debt and national debt. They are two entirely different matters. No one expects that the Banks shall repay the whole of their indebtedness at any given moment: banking would be impossible under such conditions. There is trust in the ability of the Banks to manage their debit and credit affairs so as to carry out the functions of financing and of meeting their normal obligations. Evidently, the Bank of England and the State are in a parallel position. The National Debt is largely internal; it is owed between ourselves. The interest on the debt is paid to owners of Government stock and the people who find the funds to pay this interest are the taxpayers. So, one may be in the interesting situation of paying one's self.

The post-war problem of the Government is seen to be that of conducting its affairs so as to collect the taxes needed to pay the interest on the National Debt and to finance schemes of capital reconstruction. This is not only dependent on the wealth-producing capacity of the nation but on confidence. This must mean confidence not merely in assets but in the quality and morale of the people. Because fear of the future is so worthless and undermining a characteristic, we must take into account our intangible assets of confidence and morale.

People are always ready to buy Government securities because of these factors. Is it suggested that the Government—and the people—cannot create and organise in post-war conditions to the extent that the market value of the securities making up the National Debt is kept at a sound level? This is, surely, a question of management and the State has many experienced minds in the financial field who are aware of the problems arising, such as the distribution of taxation in such a way as to avoid the checking of investment in new and needed enterprises. But these are matters of financial technique, not of national stability and power. It is not the actual size of the national debt that matters but its interest paying requirements in relation to the wealth-producing capacity of the nation and the full use of this capacity. In this connection, it should be noted that our annual output in 1942 was appreciably higher than in 1938 although large quantities of workers were removed from industry into the fighting Services. The intensification of mechanisation and the increased use of electric power have contributed a great deal to the rise in production per man-hour in industry which is probably about 6% since the war started.

When we survey these various factors in the national economy, we see that instead of regarding the size of the National Debt with fear and foreboding we are called upon to take its measure and plan and organise to meet its requirements.

Budget Balancing and Deficits

Associated with these problems is the National Budget. It is not sufficiently appreciated that the Budget has grown up from a purely cash budget into a hybrid system of accounts which does not possess a logical structure. Unfortunately, in the past, political factors have used the Budget balancing idea as a kind of weapon with which to castigate those who happened to be in power during a period of deficit.

Most organisations find it necessary to distinguish between a trading account and a capital account but the National Budget is not clear in this matter. Our practice has been the target of reformers for some time. If we turn up the pages of the 1928 "Report of the Liberal Industrial Enquiry" (Britain's Industrial Future) we find the useful suggestion that, for the sake of clearness, there should be a cash account, an income account and a capital account and that there should be a re-classification of the Budget headings. Such changes, it is advocated, would come more into line with modern conceptions of a Balance Sheet and a Capital Account, and would prevent some of the illogical—if convenient—"adjustments" which are made. "For example, the yield of the income-tax is not the amount of tax accrued and due within the year, but the amount collected and paid into the Exchequer during the period. Thus it is at the mercy of the accidents of the actual dates of payment and of the fluctuating pressure, voluntary or fortuitous, of the tax authorities. Since income tax and super-tax are collected near the end of the financial year, the above irrelevant factors may enrich or impoverish a given year's revenue at the expense, or for the benefit, of the following year by many millions."

It is true that modifications have been introduced from time to time but these have been more in the form of patchwork than of logical design. As things are, it is difficult to understand the real position from the way the Budget is made up. If, however, a distinction were drawn between current expenditure and capital expenditure, our national position would be more clear and the problem of balancing the Budget would be concerned with the current income and expenditure account only.

In this connection, how significant is a particular twelve-month period in the life of a nation, or, for that matter of a manufacturing and selling company? This is, surely,

merely a cross-section in time. The nation is continually earning and spending and its long-term position is what is important. A year is an arbitrary period and may officially terminate at any chosen month, December 31st, March 31st, June 30th . . . all these are in use among commercial enterprises, but we should be better able to judge their strength, resources and earning power if we knew the figures of their continuous processes of work. Here, the moving annual total (twelve months to the end of each month) is a valuable indicator of trend and stability.

A nation may operate with a long-term capital Budget of three, five or more years and associated current Budgets of twelve months. If the State has to step in at certain periods to compensate for the private capitalist's reluctance to spend (i.e., when economic activity is declining), it may decide to spend large sums on such vital things as houses, transport, schools and social insurance. The annual budget, as generally understood, would become unbalanced, but what about the return from this expenditure for years ahead in increased national income, well-being and health? These factors will be accumulating, and reinforcing the budgetary revenues of many years. Evidently, large-scale expenditure on socially desirable and constructive projects should appear in a capital budget.

If a budget deficit arises from such forms of spending—and from obsolete methods of accountancy—what does it signify? It results in purchasing power being finally transferred from taxpayers to the holders of Government debt. While this is happening, incomes are expanding through the use of the State's spending power at a time when it is most needed to stabilise economic activity. There is every reason to aim at balancing a properly constructed current expenditure and revenue Budget. There is every reason to put this into correct perspective in relation to the nation's plans and work of long-term wealth production.

We have dealt with economic aspects of the cost of the war, the National Debt and the Budget because so much discussion on these matters tends to follow a narrow and unreal accountancy outlook and to confuse real wealth with the means of exchange of goods and services. The result is often an unnecessary and dismal fear of the future instead of a realisation of the nation's immense resources and capacity in both material and morale.

Social Insurance Schemes

A similar approach may be made to other post-war problems such as, for example, that of social insurance, illustrated by the Beveridge Report. Neglecting the opposition to this

Plan which comes merely from interests fearing adverse effects on their revenue or financial power, we find that criticism is directed at the plan on the grounds that it is revolutionary, that "we can't afford it," and that it would undermine the people's morale, independence and spirit of adventure.

The last objection does not originate in working-class circles but comes from people who have no experience of the soul-destroying effects of continuous unemployment, poverty or the marginal existence in bringing up a family through periods of national depression. Obviously, some measure of social security is a great asset and is of the highest psychological value.

In its conception, the Plan, so far from being revolutionary, is a logical development from the social legislation of this country since 1906. It has grown naturally from the past and outlines a model for the development of social services which have expanded in line with successive increases in national income and real wages during this century. This development has acted to redistribute about 10% of the national wealth in the form of social services instead of wages. This has meant a better distribution of purchasing power—as Francis Bacon put it, "Riches are like muck; j best well spread!"

A correction to exaggeration about the cost of the Beveridge Plan is provided by analysing the total estimated cost to distinguish between what is old and what is new. Of the total £858 million reckoned as the cost of the scheme in full operation by 1965, the sum of £342 million is not new. It is the amount spent on social services in 1938 and represents, in terms of price change since that year, about £430 million. This leaves about another £430 million as the new expenditure. Further, out of this total another £110 million represents an additional national cost due to the increased number of old-age pensioners. This cost arises basically from the decline in the birth-rate since 1921 and the general ageing of the population. We are left with the sum of £320 million as the new cost due to the Beveridge proposals, although it should be noted that £90 million of this figure is the cost of Family Allowances which are not, strictly speaking, part of the plan at all.

Under the existing wage system, children become the cause of poverty. Family Allowances make the wage system more rational and encourage the birth-rate at a period when some such stimulus is most needed. Expenditure in this direction is not merely desirable; it is urgent. The late Sir Francis Freemantle estimated the national cost of ill-health, including working time lost through sickness, as £300 million a year. A great deal of this total is due to conditions which enforce on a high proportion of children in their early

years the debilitating effects of poverty. Should not our question be, "Can we afford not to provide a system of Family Allowances?"

All the foregoing figures have to be related to the national income. What this will be in 1965 is conjectural but there is no reason to suppose that, in the first post-war year, it will be appreciably different from the 1942 figure of £7,300 million. The net cost (£320 million) of the Beveridge Plan is less than 4½% of this total. Obviously, by 1965 the national income will be somewhat larger, a moderate range being £8,000 to £9,000 million. The net cost of the plan is about 3½% of this total; the over-all cost of the co-ordinated social services is about 10% of the total. How does this compare with the year 1938? Then, national income was estimated at £4,350 million and social services expenditure was £342 million or approximately 8%.

Naturally, future capacity to develop social services depends upon recovery and the level of employment after the war. The assumption of the Beveridge Plan was that unemployment would not exceed 10%. This is a sort of minimum goal which industry and the State seek. To sum up the situation in the statement by Sir Ronald Davson, "Even the higher costs of more adequate social services in the future should certainly be within our capacity to pay. With a slightly higher level of national productivity, the all-in cost of social security should still be under 10% of our total national income. Nor can this 10% be regarded as so much extra consumption; it is essentially a small redistribution of purchasing power, and that redistribution of income will be mainly "horizontal" between millions of households of modest means. It is the men and women in these households who will pay 85% of the insurance contributions and the great bulk of direct and indirect taxation . . . It will be a case of corporate self-help and the citizens as a whole will pay the bill for their own social security. They will pay partly through their contributions and partly through their rates and taxes."

The foregoing problems have been presented rather factually in order to relate wealth-producing capacity to existing commitments and probable commitments in certain important directions. Such a short analysis cannot pretend to be all-embracing but it may serve to outline a number of important facts and considerations. It is maintained that planning and initiative by individuals, industries and the State is capable of using our national resources (moral and material) so that they are fully and efficiently occupied in providing the needs of society during this vital period of fundamental change. To do this we have to work on both planes and we start by believing in our capacity to do the job.

The Suppression of Radio Interference from I.C. Engines

By H. A. MACDONALD, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E.

Henley Research Laboratories

THE suppression of radio interference is naturally a subject of considerable importance in war time, when maintenance of communications over long distances is so vital. When the receiving station is moving, radio is nearly always the only possible method of communication and a moving radio station usually has to work in the close vicinity of an internal combustion engine. All engines using petrol as a fuel have ignition circuits which, as described in a later section, broadcast a continuous series of signals covering a wide range of wavelengths. Unless suitable means are adopted for suppressing interference of this nature, reception of the wanted signal may be difficult or even impossible.

An obvious method of getting over the difficulty is to screen with metal the whole part of the ignition circuit, including battery and coil, or magneto, and all primary and secondary circuit cables. Faraday first showed that the contents of a metal cage were uninfluenced by external electric forces, and internal forces cannot affect the space outside the cage. It is no exaggeration to say that near-perfect suppression of radio interference from internal combustion engines can be obtained only in this way, and it is not surprising that bomber and fighter aircraft employ screened ignition systems extensively. The complete screening of the ignition circuits of a 24 cylinder aero engine is a complicated matter, and many patents have been taken out to cover improved methods of achieving and maintaining the electrical conductivity of the screen, and of making it possible to dismantle the screening for engine overhauls.

For road vehicles, which includes tanks, armoured cars, lorries and private cars a less drastic method of interference suppression is usually permissible. There are a number of reasons for this, as for instance the lesser average distance between transmitter and receiver, resulting in greater field strength of wanted signal at the receiver. For shorter distances of transmission, also, the signal wavelength can be raised. As the interference from an ignition circuit is greater at very low wavelengths than at low or medium wavelengths, this assists matters too. In such cases as these, the necessary degree of suppression can be obtained by the insertion of resistors or inductors in the H.T. cables of the ignition circuit.

Readers wishing to have a detailed description of the preferred methods of suppression are referred to B.S. Specification 833-1939, corrected as shown in the corrigenda sheet dated June, 1939.

This article deals almost entirely with suppression of interference by utilising resistors, and a few remarks on the theory of their action may be helpful.

Both primary and secondary circuits of any ignition systems are essentially those containing inductance and capacity, and it is well known that such a combination may be described as an oscillatory circuit. Just prior to the opening of the contact breaker points, a direct current is flowing through the primary circuit, and the powerful magnetic field produced represents a source of energy. When the contacts separate this energy must be dissipated somewhere, as the primary current must cease and the magnetic field must cease with it. A small amount of energy appears at the contacts themselves in the form of a spark, but a condenser is always connected across the points to keep this to a minimum. A much larger proportion of the energy re-appears at the plug points, where the spark fires the mixture. The current which flows to make this spark is oscillatory, the frequency of the oscillation depending on a number of factors determined by the design of the whole ignition circuit. The oscillatory currents flowing in both primary and secondary circuits can be likened to oscillatory currents flowing in the aerial of a radio-transmitter, in that, if the cables are not screened, electro magnetic waves are sent out, this being the third way in which part of the energy re-appears. But the circuits must have some ohmic resistance, and the I^2R loss represents the major part of the remaining energy which has to be dissipated. An oscillatory circuit having low resistance has a low decrement or low damping, but if considerable resistance is included, the decrement and damping are high. Resistance acts electrically just as friction does mechanically; it "puts the brake on" the oscillatory current and robs the circuit of its energy by converting it into heat. If the resistance is suitably chosen the oscillations may be damped out almost before they have started, and the broadcasting of unwanted radio signals is thereby prevented. Fig. 1 shows currents

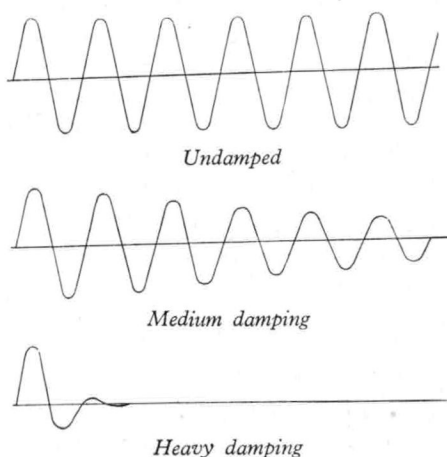


FIG. 1

flowing with no damping, medium damping and high damping respectively. The top curve is unobtainable in practice unless a continuous source of energy is provided to make good whatever losses do occur in the resistance which must be present.

It is of interest to note that the unwanted transmission from a normal ignition circuit is strongest over the range of 6 to 10 metres wavelength. Severe interference covers the range 4 to 30 metres. Interference on medium and long wave broadcasting bands covering the range 180—2,000 metres is considerably less. It may be remembered that television was sent out on a wavelength of around 9 metres, and any short-wave radio enthusiast knows that there are hundreds of stations operating within the 4—30 metres waveband, so that the advisability of suppressing the interference at the source is evident.

As Henley's have been manufacturers of ignition cables on a large scale for many years it was only natural that they should turn their attention to the design and manufacture of the type of cable having the necessary distributed resistance for achieving adequate suppression of interference of road vehicles. The requirements of such a cable were briefly:—

(1) It should resemble a normal H.T. ignition cable as regards diameter and flexibility so that it could be fitted easily to standard equipment.

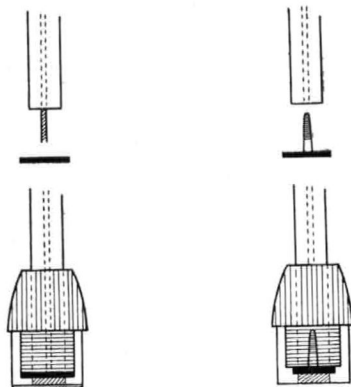
(2) Its resistance per unit length should be such that normal lengths of plug leads would provide the necessary 15,000—50,000 ohms.

(3) It should be possible to cut required lengths from a stock coil and fit the necessary terminations without difficulty.

(4) The resistance values should be reasonably constant for several years.

In view of the very great strides made in recent years in the technique of manufacture of conducting rubber, it was decided to use this medium for the high resistance path which forms the cable's conductor. Whereas only a few years ago specific resistances for conducting rubber were always well above 1 ohm per centimetre cube, it is nowadays possible to get values down to a fraction of 1 ohm. A simple calculation will show that a resistance value of about 25,000 ohms will be obtained for an average 18 inch length of plug lead, using a conductor diameter of $1\frac{1}{2}$ mms. and a specific resistance of 10 ohms per centimetre cube. In this country the external diameter for H.T. ignition cables has been widely standardised at approximately 7 mms., so that a $1\frac{1}{2}$ mm. conductor gives a $2\frac{3}{4}$ mm. radial thickness of insulation, which is adequate for normal coil and magneto voltages. Flexibility is adequate with a cable of this type, but a warning is necessary regarding the inadvisability of applying sharp bends or large stretching forces, either of which will tend to increase the resistance of the conductor permanently.

Terminations are not such a difficult matter as might be expected. The majority of Lucas terminals in distributors and on coils take the form of a moulded nut (like a gland nut) which slides over the cable, and is used to clamp the spread-out wires of the normal conductor to a fixed metal contact (see Fig. 2). Others take the form of a projecting steel spike over which the cable is clamped by pressure from a cap, thus causing the spike to pierce the insulation and make contact with the conductor. Terminations

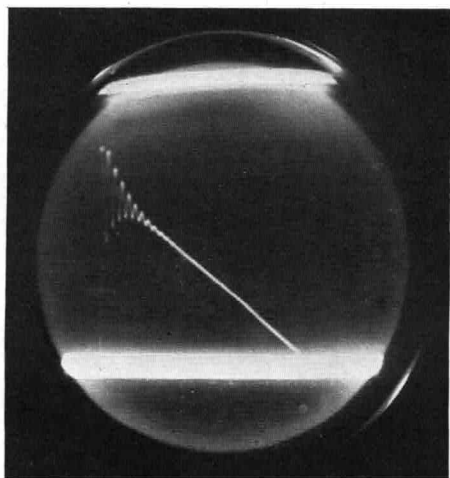
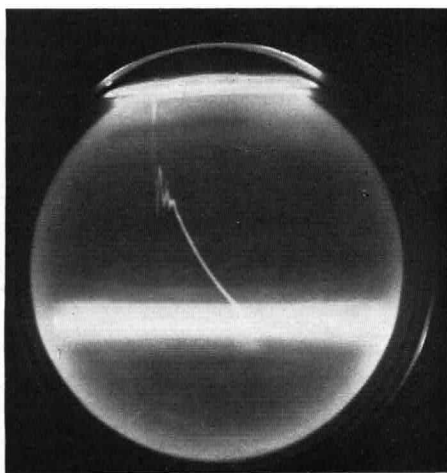


NORMAL CABLE

FIG. 2

HIGH RESISTANCE
CABLE

FIG. 3

FIG. 4. *Standard Cable.*FIG. 5. *High Resistance Cable.*

at plugs often take the form of a brass sleeve which is slipped over the end of the cable, the sleeve having in addition a central spike which forces its way between the wires and the insulation. When using Henley high resistance ignition cable, only the "gland nut" type of termination has been found to require making off in a non-standard manner, and even in this case the modification is very simple. The gland nut is threaded on to the cable in the usual way, and a "drawing pin" with a thickened and screwed shank is inserted into the exposed end of the cable. The gland nut then clamps the "head" of the "drawing pin" to the contact (see Fig. 3). Terminating a high resistance cable in this way is actually quicker than with the standard cable, as no trimming or wire spreading is necessary.

So far as maintenance of resistance over long periods is concerned, evidence has been obtained of satisfactory performance over a period of three years on a private car which covered approximately 45,000 miles during that time. No adverse effect on engine performance was noted, and the resistance value at the end of the period was within 5% of the original value.

A great many tests have been carried out in the Henley Research Laboratories on cable of this type, including the determination of conductivity with variations in ambient temperature, applied voltage, and effective frequency. A cathode ray oscillograph has been used to determine changes in the wave form of the current in the H.T. circuit brought about by the use of this special type of cable, and examples are given in Figs. 4 and 5 in the

form of actual photographs of the screen of the C.R.O. taken while a single spark was made to jump the points of an ordinary plug. Due to the fact that the introduction of the C.R.O. circuits necessarily introduced some damping into the system employing the standard cable, the oscillations appear to have been damped out more rapidly than they would have been in practice. Nevertheless, the improvement obtained by using the H.R.I. cable is obvious.

From the more practical point of view it might be asked "Why should a high resistance cable be purchased in preference to a lumped resistor or inductor?" There are several reasons, some of the more important ones being :—

(1) Tests carried out by more than one Government Department have shown that the suppression obtained by a distributed resistance of the H.R.I. cable type is greater than that obtained by a lumped resistor. Details of the many tests carried out on this cable by various Research Organisations as well as Government Departments cannot of course be published until after the end of the war.

(2) Resistors or inductors are more vulnerable to damage by accidental blows from tools, etc.

(3) They are easily recognisable for what they are, and may therefore be "lost," whereas H.R.I. ignition cable cannot be distinguished readily from the normal cable.

(4)* The imaginative type of driver will always convince himself that the use of resistors or inductors is adversely affecting engine performance, and it is much easier to

remove or short-circuit them than to replace H.R.I. cable with normal cable.

In the author's opinion legislation is called for to make use of the suppression devices compulsory on all road vehicles after the war. Television was making rapid strides up to 1939, and we have every reason to hope that we shall get stereoscopic colour television when peace time research has had a chance. The author has seen the effect, on a domestic television screen, of his own car "ticking over" outside the house. The picture was almost unrecognisable owing to "snow-storm" effects. Without moving the car, the ordinary H.T. cables were replaced by Henley H.R.I. cables, and no trace of interference was apparent no matter at what speed the engine was run. Both from the view of the television and the short wave radio user, every road vehicle with a petrol engine is a mobile transmitter causing variable interference, and as suppression of this can be carried out so readily, as indicated in this article, it is only fair that the road user should be made to co-operate in the few cases where he will not do so voluntarily.

Birthday Messages

The kind messages from overseas which we abstract below unfortunately arrived too late for inclusion in the last issue, our fifteenth birthday number.

From MESSRS. TURNBULL & JONES, LTD.,
CHRISTCHURCH, NEW ZEALAND.

"DISTRIBUTION," as the name implies, is a subject containing many problems especially for supply companies and their distributing engineers. Through the agency of your publication, these problems and other experiences interesting to the electrical profession are collated and placed before those interested in a concise and illuminating form, the appreciation of which could not possibly be told in these few lines.

May we offer our heartiest congratulations and best wishes for the future of your journal which we feel has taken a prominent place in technical publications."

From HENLEY'S, CALCUTTA.

"DISTRIBUTION" is established in India as an important publication of the British electrical industry, and there is general approval of the manner in which war-time difficulties have been overcome."

Cablegram from HENLEY'S, SYDNEY.

"Australian recipients eagerly look forward to receipt of "DISTRIBUTION." Have received many expressions, gratification continuance of publication under such difficult conditions."

(Signed) RUTTY.

Loading Charts for Low Voltage A.C. Cables

By T. G. PARTRIDGE, M.I.E.E.

THE approximate curves illustrated were designed some time ago by the Author, and have served him as a rough and ready guide in selecting L.V. cable sizes for any particular duty, and also broadly to act as a check on results of calculations worked out by formulae.

It is hoped these charts will prove of interest and be of some service to distribution engineers generally. The curves show at a glance the approximate load/length for a drop of one volt for each size of cable. The range of 4-core and 2-core cables shown may very well cover the sizes required by an Undertaking for services and distributors on the L.V.A.C. system now adopted as standard in Britain, namely 3-phase 4-wire 400/230 volts 50 cycles, with the centre point solidly earthed.

Only three sizes of cut-outs for services are given:—

- (1) Up to 60 amps. — 60 amp. cut-out.
- (2) 60 to 100 amps. — 100 amp. cut-out.
- (3) 100 to 300 amps. — 300 amp. cut-out.

Approximate maximum safe loads are also indicated.

Example (1).

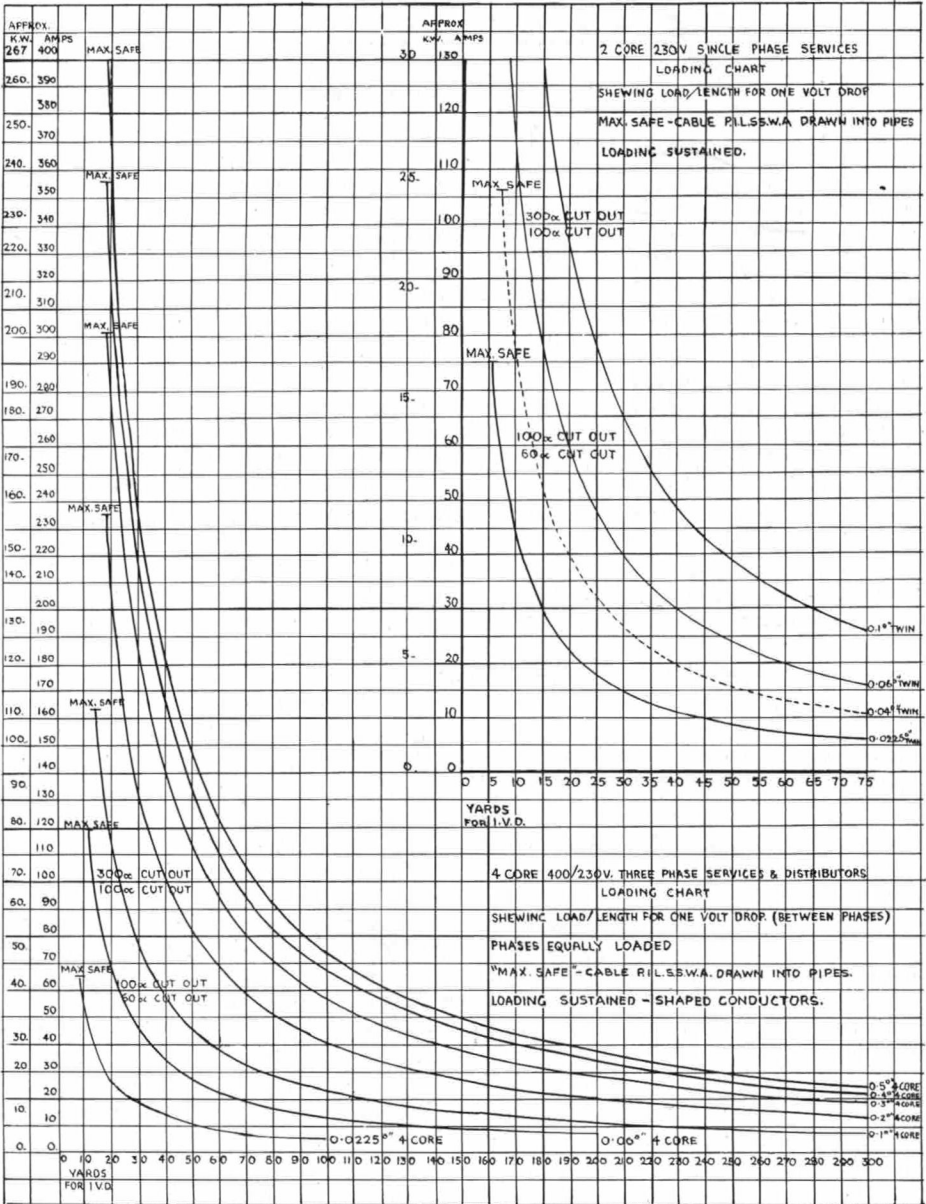
A 3-phase balanced load of 100 amperes will give one volt drop between phases as follows:—

Size 4-core .06 sq. in. approximately 13 yards.
Size 4-core .1 sq. in. approximately 23 yards.
Size 4-core .2 sq. in. approximately 41 yards.
Size 4-core .3 sq. in. approximately 56 yards.
Size 4-core .4 sq. in. approximately 66 yards.
Size 4-core .5 sq. in. approximately 73 yards.

Example (2).

A continuous balanced 3-phase load of 80 kW at 0.8 p.f. is to be transmitted 120 yards: the voltage drop between phases allowable is 5. What conductor size is necessary?

The corresponding current on the chart for this load is that for 100 kW (very nearly) i.e. 150 amps. The first intercept is at 15 yards on the 0.1 sq. in. curve. Hence 5 volts drop will occur in a 75 yards run—too short. The 150 amp. intercept on the 0.2 sq. in. curve is at 26½ yards, so that for 120 yards the drop will be approximately 4.5 volts. 0.2 sq. in. is then the required conductor size.



This is a reproduction of the original chart 22" x 17".

For more accurate reading a limited number of the original charts are available on request.

Concluded from page 198

Welding owes much to electrical engineers but it can offer resources in return that deserve to be utilized still more widely. If these

possibilities are realised then there is no need to search further for a solution to many of the problems with which those responsible for maintenance and installation work must deal in the course of their duties.

The Construction of Nomograms

By E. C. WOODS, B.Sc.

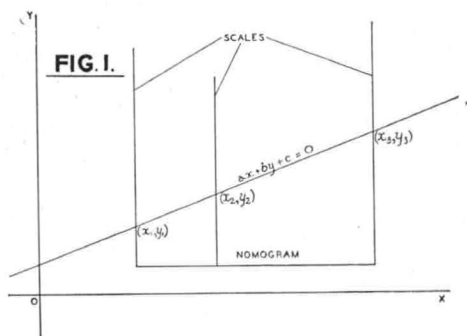
Henley's Tyre & Rubber Co., Ltd.

NOMOGRAPHIC charts are so common to-day that it is quite unnecessary to describe either their form or their use: however, full benefit of the devices will not be reaped until the knowledge of their construction is as widely known as the drawing of a graph or the use of a slide-rule. This article is intended as an elementary introduction to the subject about which a few books and many advanced treatises have been written: it describes how simple nomograms can be constructed to represent a certain type of relation which, although of almost the simplest class, nevertheless has considerable application in practice and it is hoped that some encouragement will be given for the construction of such charts where repeated calculations of a similar kind are made, especially where those calculations involve tedious repeated references to tables or use of slide-rules.

The particular type of nomogram to be examined is that consisting of three straight vertical scales representing values of three related variables. Now the equation of any straight line is $ax + by + c = 0$ where x and y are the cartesian co-ordinates of any point on the line and a , b and c are constants. Therefore, if the line cuts the three scales of our nomogram at points (x_1, y_1) , (x_2, y_2) and (x_3, y_3) respectively, referred to any axes drawn on the chart so that abscissæ are measured perpendicular to the scales and ordinates parallel to the scales (see fig. 1).

$$\left. \begin{aligned} ax_1 + by_1 + c &= 0 \\ ax_2 + by_2 + c &= 0 \\ ax_3 + by_3 + c &= 0 \end{aligned} \right\} \dots (1)$$

For the moment, it must be pointed out that the co-ordinates are determined on arbitrarily selected scales and do not necessarily bear any obvious relation to either the values marked on the scales or the physical dimensions of the chart. If we select the axes of the co-ordinate system so that the vertical axis corresponds with the extreme left hand nomographic scale, $x_1 = 0$ then:



$$\left. \begin{aligned} by_1 + c &= 0 \\ ax_2 + by_2 + c &= 0 \\ ax_3 + by_3 + c &= 0 \end{aligned} \right\} \dots (2)$$

from which we can easily eliminate a , b and c and obtain

$$y_1 (x_3 - x_2) + y_3 x_2 = y_2 x_3 \dots (3)$$

or since x_2 and x_3 are constants for the infinite number of lines which can be drawn across the chart

$$1 y_1 + m y_3 = n y_2 \dots (4)$$

Where 1 , m and n are also constants.

Now if the nomographic scales are uniformly divided and scaled with values of variables u , v and w , respectively, so that

$$\left. \begin{aligned} y_1 &= \alpha u_1 \\ y_2 &= \gamma w_1 \\ \text{and } y_3 &= \beta v_1 \end{aligned} \right\} \dots (5)$$

where the zeros of the scales lie in the "x" axis,

$$\text{we have } -\alpha u_1 + m \beta v_1 = n \gamma w_1 \dots (6)$$

Eqn. (6) shows that the particular values of u , v and w satisfy the equation.

$$r u + s v = t w \dots (7)$$

for all straight lines (or "secors," as they are called) which cut the three nomographic scales uniformly divided for values of the connected variables u , v and w . We are then examining the form of nomogram which represents this relationship.

Now the simplest form of equation (7) is

$u + v = w$ (representing, for example, the total resistance w given by two resistances $u + v$ in series) so that the coefficients of u , v and w in equation (6) are each unity.

Then from equations (3) and (5),

$$\left. \begin{aligned} \alpha(x_3 - x_2) &= 1 \\ \beta x_2 &= 1 \\ \text{and } \gamma x_3 &= 1 \end{aligned} \right\} \dots \dots \dots (8)$$

where we have three equations to solve for the five unknowns. It is necessary to select values for two of the constants either from the required ranges of values of the variables or the limiting size of the nomogram it is required to construct.

For example, suppose we wish to construct a nomogram representing the sum of the resistances u and v in series where both u and v are required to range from 0 to 100 Ω and, for the accuracy required, both the ranges of u and v can be represented on scales 10" in length. It follows (from equation 5) that

$$\alpha = \frac{10}{100} = \frac{1}{10}$$

$$\text{and } \beta = \frac{10}{100} = \frac{1}{10}$$

and therefore, from equation (8)

$$\begin{aligned} x_3 - x_2 &= 10 \\ x_2 &= 10 \\ \gamma x_3 &= 1 \end{aligned}$$

$$\text{Then } x_3 = 20 \text{ and } \gamma = \frac{1}{20}$$

It follows that we can make the overall size of the nomogram 10" $\times$ 10" by making the horizontal unit $\frac{1}{2}$ " so that $x_2 = 5$ " and $x_3 = 10$ " and the scales are divided so that any value, say R , of any one of the variables is located at a distance αR , βR or γR above the zeros of the scales which are on the "x" axis, according to whether R is a value of u , v or w respectively. The completed nomogram is shown in Fig. 2.

The combination of two resistances r_1 and r_2 in parallel results in an exactly analogous equation ($\frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{R}$) to that considered and the complete manipulation to construct a nomogram will be explained in some greater detail.

In this case, comparing the given equation with equation (5), we see that $y_1 = \alpha \frac{1}{r_1}$ etc., therefore, the scales must be evenly divided for values of the *reciprocals* of the separate variables.

Suppose we require the values of r_1 to range from 10 to 50 Ω and of r_2 to range from 50 to 75 Ω and that sufficient accuracy will be given by scales 5" in length. We find the values of α and β , the scale factors as they are called, as follows:—

Range of r_1 ... 10 to 50

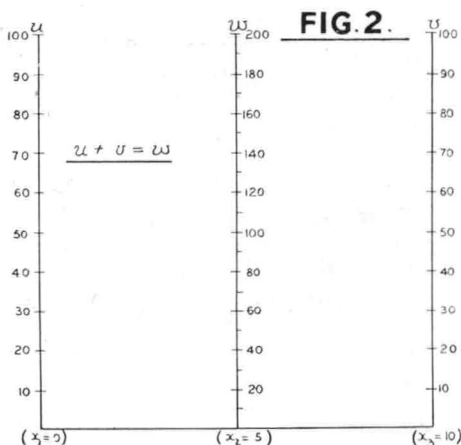
Range of $\frac{1}{r_1}$ 1 to .02

$$\therefore \alpha = \frac{5}{.1 - .02} = \frac{5}{.08} = 62.5$$

Range of r_2 ... 50 to 75

Range of $\frac{1}{r_2}$ 02 to .0133

Now this is an arbitrary factor and we can select any convenient value to suit the size of scale; in this case $\alpha = 60$ will give a scale of approximately 5" length for the given range of values.



$$\therefore \beta = \frac{5}{.02 - .0133} = \frac{5}{.0067} = 750$$

which again is arbitrary but in this case the value 750 is convenient enough.

$$\text{Now } \alpha (x_3 - x_2) = 1$$

$$\beta x_2 = 1$$

$$\gamma x_3 = 1$$

$$x_2 = \frac{1}{750} = .00133$$

$$x_3 = \frac{1}{60} + \frac{1}{750} = .018$$

$$\text{and } \gamma = \frac{1}{x_3} = 55.5$$

and so, by taking the horizontal unit to be 300"

$$x_3 = .018 \times 300 = 5.4''$$

$$\text{and } x_2 = .00133 \times 300 = 0.4''$$

In order to construct the scales it is convenient to set out the following table :—

$r_1 \Omega$	10	15	20	30	40	50
$\frac{1}{r_1}$	.1	.067	.05	.033	.025	.02
$\alpha \frac{1}{r_1}$ ins.	6	4	3	2	1.5	1.2
h_1 ins.	4.8	2.8	1.8	0.8	0.3	0
$r_2 \Omega$	50	55	60	65	70	75
$\frac{1}{r_2}$	.02	.018	.017	.015	.014	.013
$\beta \frac{1}{r_2}$ ins.	15.0	13.68	12.54	11.56	10.74	10
h_2 ins.	5	3.68	2.54	1.56	.74	0
$R \Omega$	8	10	15	20	25	30
$\frac{1}{R}$	.125	.1	.067	.05	.04	.033
$\gamma \frac{1}{R}$ ins.	6.94	5.55	3.7	2.78	2.22	1.84
H ins.	5.10	3.71	1.86	.94	.38	0

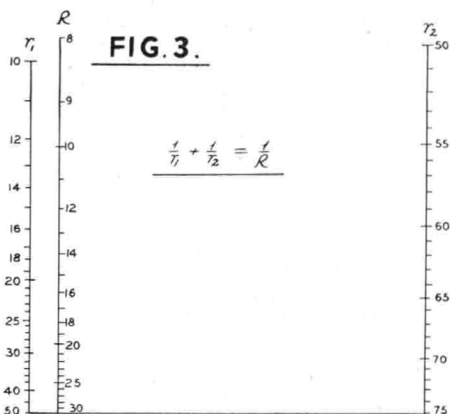
In the first place the principal values of r_1 which are required to be shown on the scale are written down and below them are entered the corresponding values of $\frac{1}{r_1}$. Then $\alpha \frac{1}{r_1}$ is calculated for each value and since we are using a scale of $\frac{1}{r_1}$ which does not extend to zero (indeed the zero is at $r_1 = \infty$) the next line (h_1) shows the differences between the lowest value and each of the others; the lowest value can then be used as a datum point in scaling off all the other points. The table is completed by similar calculations for r_2 and R , the range of the latter being obtained from the extreme combinations of r_1 and r_2 i.e. 10 Ω with 50 Ω and 50 Ω with 75 Ω : it will be found that the corresponding values of R are $8\frac{1}{2} \Omega$ and 30 Ω respectively so values $\gamma \frac{1}{R}$ are calculated for the range of R from 8 to 30.

The geometrical construction of the nomogram commences by drawing three vertical lines to represent the scales r_1 , r_2 and R , their distances apart being defined by x_2 and x_3 , that

is to say, the distance between the r_1 and R scales is x_2 , (0.4") and the distance between r_1 and r_2 scales is x_3 , (5.4") both r_2 and R scales being on the same side of r_1 . In order to align the diagram correctly it is necessary to check that particular values, one on each scale, numerically satisfying the equation $\frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{R}$ lie on any straight line across the diagram. If this is so, all other corresponding points are collinear when the vertical scales are completed. (This can be proved quite simply). As mentioned above, $r_1 = 50$, $r_2 = 75$ and $R = 30$, satisfy the equation, hence these points are arranged on the scales to lie on a straight line which is conveniently to the base line, and the remaining points are scaled off on the appropriate scales according to the heights h_1 , h_2 and H in the table and denoted by the corresponding values r_1 , r_2 and R .

The result is shown in fig. 3.

In the above description, only simple algebra and elementary co-ordinate geometry has been used in dealing with the particular case of three related variables which can be represented in a chart of three straight vertical scales. The interested reader, however, will find that calculations can be made much more quickly and neatly by employing determinants, a method which is fully described in *The Nomogram* by Allcock & Jones (published by Pitman). The method we have described can be used for the representation of any relation involving these variables which can be written in the form $f(u) + F(w) = \phi(v)$; for example, Ohm's Law $R = \frac{E}{I}$ can be written $\log R + \log I = \log E$, where the scales will be divided proportionate to the *logs* of the variables R , I and E instead of the reciprocals of the variables as in the example above. The constants require to be determined, of course, in exactly the same manner as shown with due consideration of the ranges involved and the size of the chart required.



Similar relations which can be dealt with in the same way are, in their nomographic form, as follows. Their more usual form will easily be recognized.

$$c_1 + c_2 = C \text{ and } \frac{1}{c_1} + \frac{1}{c_2} = \frac{1}{c}$$

For condensers.

$$\log c + \log 4\pi d = \log K A$$

For a parallel plate condenser.

$$\log I^2 + \log R = \log W$$

The power equation.

$$\log 4\pi I + \log H = \log B$$

Magnetic induction.

$$\log R_0 + \log (1 + a t) = \log R_t$$

The temperature/resistance

relationship—and numerous others both in Electrical and other branches of Engineering Science. It will be found that the most convenient nomogram is given when the scales of the known variables are the outside ones and therefore, in some cases (e.g. when the value of the current is required from definite conditions of voltage and resistance), it will be found advantageous to rewrite the basic formula, $f(u) - \phi(v) = F(w)$ (i.e. $\log E - \log R = \log I$). Where the calculations follow exactly as above provided due regard is given to the change in sign of $\phi(v)$.

The reader of *The Nomogram* will find that the particular type we have studied is referred to as being of the third class genus zero type, whilst the relations between a larger number

of variables, perhaps including functions of a more complicated nature e.g., $S = \frac{E}{r \log_e (R)/(r)}$ for the maximum dielectric stress in a single core cable can be transformed into a nomographic form of higher class and genus and the construction of the appropriate scales is only slightly more complicated.

High Voltage Measurement at Power Frequencies in Cable Testing Laboratories

By T. R. P. HARRISON, B.Sc.Tech. M.I.E.E.

Henley Research Laboratories.

THE subject of the accurate measurement of high voltages is one which has received considerable attention from many investigators during the past twenty years. As an instance of the difficulties encountered, the immense amount of investigation on the sphere gap may be cited, the results of which have been published from time to time.

As a device for frequent voltage measurement however, the sphere gap has many disadvantages which are well known. A number of methods which are more convenient and sufficiently accurate for normal purposes are available. Most of these use low voltage meters and some means for stepping down the high voltage such as

- (1) Capacity Potential Divider.
- (2) Resistance Potential Divider.
- (3) Potential Transformer.

These methods are all independent of the load on the main transformer and each has its advantages and disadvantages, particularly when voltages of 500,000 or more are under consideration.

It will be readily appreciated that such methods are satisfactory in laboratories using a single transformer engaged in testing samples of small capacity such as porcelain insulators, but for cases where many transformers are in operation simultaneously it is more convenient to measure voltages by primary input, tertiary winding or tapped secondary winding on each transformer, using the direct high voltage appliance as a reference standard only. The choice of method employed depends upon individual circumstances but accurate results are only obtained in any particular case if due care is taken to ensure that the inherent shortcomings of the method selected are fully understood and allowances made for them.

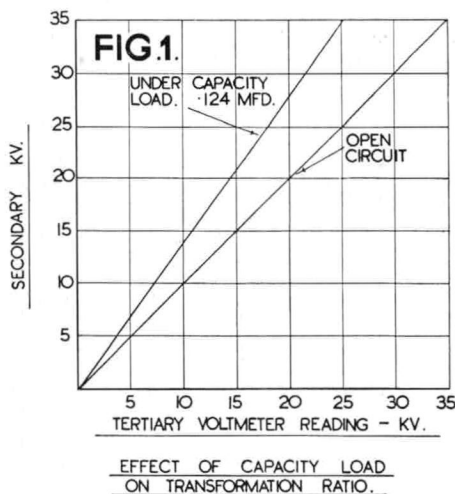
It is felt that it would be helpful to record the methods which have been adopted in the Henley High Voltage Laboratory, as these apply particularly to cable testing and have proved satisfactory over a long period.

1. The Particular Case of the Cable Laboratory

The most important factor to be remembered when dealing with cable testing is that the samples under test have a much higher capacity than for other types of apparatus, such as insulators and switchgear. This capacity is a very variable quantity dependent

upon the sample length and will exert a varying influence according to the test in hand and the equipment being used. The current taken from the secondary winding of the transformer is almost pure leading current having a power factor of the order of 0.006 and it will be evident that this produces an increase in the transformation ratio. The effect is opposite to that normally experienced with commercial loads on power transformers.

The significance of this and the extent to which it occurs may not generally be appreciated. Fig. 1 shows the open circuit secondary voltage and the true secondary voltage plotted against tertiary winding voltage for a 125 kV 100 kVA transformer testing a 440 yard length of 33 kV single core cable, from which the "self excitation" effect is apparent and is seen to be of the order of 30%.

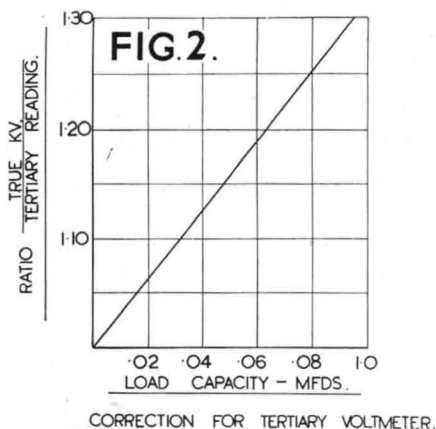


2. Application for Normal Cable Testing

Testing transformers of modern design for cable laboratories usually have electrostatic screens inserted round the primary winding and also between the primary and secondary windings for the purpose of ensuring accuracy during power factor testing. A tertiary voltmeter winding is also incorporated and as power factor tests are taken over a wide voltage range, readings from this tertiary winding permit of high testing speeds.

The voltmeter load on the tertiary winding being always constant, the transformation

ratio primary/tertiary is substantially independent of main load on the secondary winding. Consequently any voltmeter reading on the tertiary winding will be too low with the transformer under heavy capacity load. This may be easily overcome by a determination of the true secondary voltage for any capacity load and the plotting of a correction curve giving the ratio of $\frac{\text{true kV}}{\text{tertiary indication}}$ as a function of capacity. This curve for the transformer mentioned in Section 1 is shown in Fig. 2.



The use of such a curve gives satisfactory results but suffers from the following disadvantages:—

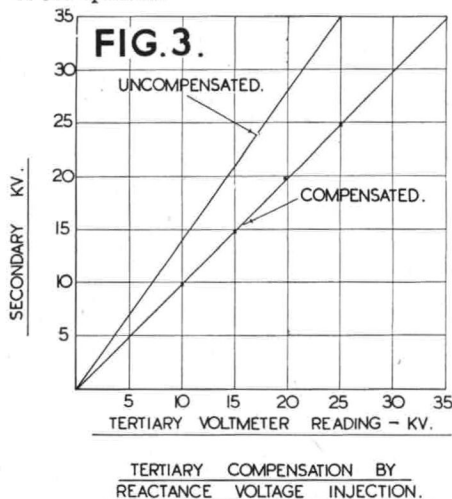
- (1) An accurate knowledge of the capacity of the sample under test is necessary beforehand.
 - (2) The operator must choose the true corresponding correction.
 - (3) Speed of testing is sacrificed if much work on different samples is being undertaken.
3. Automatic Correction of Tertiary Voltmeter Reading

These disadvantages have been overcome in a simple way which has proved most efficacious and is sufficiently accurate for normal purposes.

The amount by which the tertiary voltmeter does not indicate the true secondary voltage is proportional to the capacity load. In order, therefore, to compensate for the difference a voltage must be applied to the tertiary winding which is proportional to the load and introduces the correct degree of compensation.

The required result is obtained by inserting a suitable reactance between the low voltage end of the secondary winding and earth. The voltage developed across this reactance is injected into the tertiary voltmeter winding circuit so as to boost the indication on the voltmeter.

Fig. 3 shows the results obtained with and without this compensation. The reactance used is quite small as is seen from Fig. 4. In this way the compensation for the effect of the high capacity load is effected substantially correctly in all cases and quite independently of the operator.



4. Direct Indication of High Voltage

The foregoing has dealt with the general method in use for measuring high voltage and is applicable to tests being taken on a number of transformers on different jobs simultaneously. Usually the testing equipment is remotely controlled and the control desks are situated in the control room adjacent to the testing bridges.

When, however, voltage is being applied to a sample of cable complete with sealing ends and observations are being made on the commencement and extent of visual corona by observers on the test floor, it is necessary to have an indication of voltage at any moment quite independently of instruments on the control desk, this indication being visible from any point on the test floor.

Most cable laboratories are equipped with a high voltage standard condenser used as the reference for power factor tests as part of the normal Schering Bridge equipment. Such condensers are usually filled with inert gas under pressure and have a capacity round about 0.0001 mfds. Fig. 5 shows such a condenser for use up to 300 kV having an overall height of six feet. The capacity of

The Burden of a Current Transformer

By G. W. STUBBINGS, B.Sc., A.M.I.E.E.

A CURRENT transformer has two distinct ratings. The first is the ratio which is expressed in a form which gives the full load primary and secondary currents explicitly. Thus if a transformer is rated as 100/5, this means not only that the secondary current is nominally one-twentieth of the primary current, but also that the full load primary and secondary currents are respectively 100 and 5 amps. The second rating is the burden, which is defined as the product of secondary current by secondary terminal voltage with full load primary current flowing, for which certain specified errors of ratio and phase will not be exceeded. With a standard full load secondary current value, the VA burden is fixed by the impedance in ohms of the external secondary circuit. Thus, if the full load secondary current is nominally 5 amps, the VA burden is very approximately 25 times the external impedance in ohms. The VA burden output of a transformer always refers to full load conditions. If a transformer with a burden rating of 15 VA is specified to have a ratio error not exceeding 1 per cent with one-tenth full load current, the 15 VA figure does not apply to the secondary output with one-tenth full load current in the primary windings, but to an impedance value of the secondary circuit that would give 15 VA of output with full load current. Actually the secondary output at one-tenth of full-load would be about 0.15 VA because, for a given impedance of the secondary circuit, the secondary voltage is proportional to the primary current. As will be seen hereafter, the errors of a current transformer depend not only upon the VA value of the secondary output at full load, but also upon the power factor of this output, or upon the ratio of resistance to impedance of the secondary circuit. For this reason the rated burden with which stipulated errors will not be exceeded is not only specified in VA, but also in terms of the characteristics of the external secondary circuit. Usually, rated burdens are specified in respect to non-inductive external secondary circuits, that is those having an external power factor of unity.

The burden of a current transformer as defined above does not correspond to the total VA consumption in its whole secondary circuit. Voltage is required to force the secondary current through the secondary windings, so that the whole burden, equal to the product of full load secondary amps by the corresponding induced e.m.f. in volts, can be conceived to be the resultant of two components

namely, the VA consumption of the external circuit and the internal VA consumption of the secondary winding. The power factor of the total burden will depend upon the power factors of these two components. The impedance of the internal burden depends upon the resistance and the leakage reactance of the secondary winding of the transformer. In a bar-primary transformer with a secondary winding uniformly disposed on a ring-shape core, the leakage reactance is generally considered to be negligibly small, so that the power factor of the internal burden is unity.

The errors of a current transformer are due to the exciting current required to produce the induced e.m.f. necessary to drive the secondary current against the impedance of the whole secondary circuit. These errors, therefore, depend upon the total burden, and, even if the external burden is reduced to zero, there will still be residual errors because voltage is required to drive secondary current through the short-circuited secondary winding. The exciting current which causes the errors may be conceived either to be abstracted from the primary current before transformation at the nominal ratio, or to be shunted from the external secondary circuit after complete transformation. According to the latter conception the action of a current transformer is equivalent to the circuit shown in Fig. 1. Here T is a perfect transformer, free

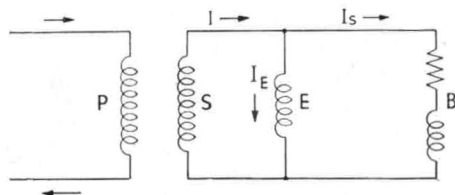


FIG. 1

from errors, and of the same ratio as the actual transformer. B is the external circuit having an impedance corresponding to the total burden, internal and external, of the actual transformer, and E is a coil which, for any value of the secondary e.m.f. of T, shunts from B a current corresponding to the exciting current of the actual transformer for this value of the induced e.m.f. The current I_s passing into B is always less than the current I delivered by the perfect transformer, and, unless the power factors of the B and E circuits are the same, I and I_s will be out of phase.

These differences of magnitude and phase of I and I_s are the ratio and phase errors of the transformer corresponding to the shunting circuit E . An increase of the impedance of B without change of power factor will increase both ratio and phase errors. A change of the power factor of B without change of impedance will change ratio and phase errors in opposite directions. Thus, as the phase angle of B approaches equality to that of E , the phase error will decrease and the ratio error will increase. If the phase error is expressed in centiradian measure, then, with constant total burden impedance, the sum of the squares of the ratio and phase errors will be constant and equal to the percentage value of the total secondary current shunted from B by E .

Although rated burdens are normally specified as non-inductive, the actual working burdens of current transformers are usually partly inductive. This gives rise to the following kind of question that is sometimes asked by practical men: given that the ratio error of a transformer for a 5 VA non-inductive burden does not exceed 0.5 per cent, what will be the limit of error for a burden of 2 VA consisting of an induction meter current coil? It is impossible to answer a question of this kind precisely with the information given, because errors depend upon ohmic value and power factor of total burden, so that, even if the power factor of the 2 VA meter coil was known, the total burden characteristics could not be found without information about the internal component of the burden. The problem is further complicated by the circumstance that the exciting current causing the errors is not proportional to secondary e.m.f. and, therefore is not proportional to total burden impedance with given secondary current. As most industrial current transformer burdens have a power factor of less than unity, there would be some advantage in specifying limits of error at a burden power factor corresponding to some kind of average value to be expected in practice. This kind of specification, together with a further specification of the VA value of the internal burden, would facilitate approximate estimates of the limits of error to be expected with burdens less, or even, slightly greater, than the rated values.

When the current transformers are used solely to supply A.C. energy meters, the burden comprised in the coils of the meters is small, and in certain circumstances, where the meter is remote from the transformers, the greater part of the external burden may be due to the impedance of the connecting leads. If a 3-phase meter is connected to two current transformers by three leads, one being a common return for the two meter elements, the current in this common return, from the

meter to the transformers, will be 60 degrees out of phase with each meter current, leading in respect to one and lagging with respect to the other. The voltage drop in the common return lead will likewise be out of phase with the voltage drops in the other leads which carry the meter currents, so that the common return lead will virtually be an inductive impedance in circuit with one meter element and a capacitive impedance in circuit with the other. The effective burdens of the two current transformers will thus be unequal in ohmic impedance and also in power factor, so that, even though the two transformers are of identical design, and have equal errors with equal burdens, the actual ratio and phase errors in the meter current coils will be unequal. This will tend to impair the balance of the two elements of the meter. The unsymmetrical effect of the common return lead can, of course, be avoided by using four connecting leads between the meter and its current transformers, two for each element. The ratio and phase errors of the two similar transformers will then be equal and will correspond to a burden which can be exactly simulated when the meter is tested.

Summarising the preceding remarks, we may say that the actual errors of a current transformer depend upon the VA and power factor of the consumption in its external secondary circuit, while the rated burden is the unity power factor VA consumption for which stipulated limits of error will not be exceeded. The precise particulars of the actual burden of a current transformer cannot easily be computed, since the VA in this burden is a vector sum, but an appropriate value of this VA can be obtained by adding the several VA consumptions in the components of the whole external circuit, including that in the connecting leads. The power factor of the actual burden will generally be less than unity and, as low power factor increases ratio errors, the approximate burden so computed, should be somewhat less than the rated burden, if the stipulated limits of error are not to be exceeded. When two current transformers in a 3-phase circuit are used for the measurement of energy by a 3-phase meter, and also for the operation of other instruments or relays, these transformers should be of identical type, and the separate burdens should be identical in character, to avoid the effect of unbalance in a 3-phase meter which, as mentioned above, is caused by inequalities in the ratio and phase errors of the two metering transformers.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in this magazine should not be taken as an indication that they are necessarily available for export.

Some New Ideas in Mathematics

By C. TURNBULL, M.I.E.E.

IN his *Introduction to Mathematics*, Whitehead tells us that novel ideas in mathematics need not come from vast knowledge but rather from an unusual assortment of ideas, and also from someone who has the courage to get away from routine. Thus it was a great advance when Harriot wrote $x + y - 1 = 0$ instead of $x + y = 1$: probably no one thought anything of it at the time but it made possible the modern conception of algebraic form. My own interest arose from the study of that remarkable book by Clifford and Karl Pearson, *The Commonsense of the Exact Sciences*, which shows that axioms are not eternal truths, but conventions which may be varied to suit. Subsequently I worked on my *Method in Invention* system, published in *Distribution*, and I have found that the methods work admirably in mathematics as in other fields.

Over a quarter of a century ago, after much trial, I succeeded in getting at the mechanisms of the Differential Calculus and found that much of it could be worked logically without infinitesimals. Consider the equation $y = x^2$ and let P be a point on the curve whose co-ordinates are X, Y. Move the origin to this point and the new equation becomes $y = 2Xx + x^2$, where x, y are now measured from P, and X, Y from the first origin. Edwards' *Calculus* shows that the equation to the tangent at P is $y = 2Xx$ and indeed this is obvious because it is a line through P and is separated from the curve at all other points by the distance $y = x^2$ so that the curve is on the same side of the line at all positions. The slope of the tangent is $y/x = 2X$ and this is true for any length of the tangent and hence for an infinitesimal length for which we may write $dy/dx = 2X$. Also, as by a reasonable convention an infinitesimal piece of the curve may be considered to coincide with the tangent at the point of contact, we may agree to say that the slope of the curve itself is $dy/dx = 2X$ in this case. We have thus found the slope of the tangent without using infinitesimals and have found the slope of the curve itself by a convention. The meaning of the infinitesimals thus becomes clear and reasonable and there is nothing of the "ghosts of departed quantities" about them that Bishop Berkeley jeered at. We have also a definition of the word "small" so often used in mathematics. It is an illogical word as x itself may also be small if we are dealing with curves of atomic proportions. The fact is we have not discarded $(dx)^2$, etc., because such quantities are small but we have selected the dx and dy terms because these

deal with the tangent and that is what we are interested in. The difference between neglecting and selecting is of great importance; it is the difference between inaccuracy and accuracy and that is something in mathematics.

But what of curves of a more complicated nature? The same method shows that the equation to the tangent to the curve $y = x^n$ at the point X, Y, is $y = nX^{n-1}x$ and that its slope is $y/x = nX^{n-1}$. Hence if the equation to a curve has the form $y = Ax^0 + Bx + Cx^2 + \dots$ the slope of its tangent will be $Bx^0 + 2Cx + \dots$, which is the same result as obtained by use of infinitesimals. Also by convention, the slope of the curve at the point of contact will be the same.

The advance marked by this method of dealing with the calculus can only be seen by those who have studied the long involved explanations given in the philosophy of infinitesimals. Whitehead tells us that Leibniz believed in nothings of varying sizes, that Newton's explanation was unsatisfactory and that Weierstrass solved it by the idea of any standard of approximation. All this disappears when we see that the process of differentiation places the origin on the curve and that we select certain terms because they refer to the tangent and that we do not neglect terms because they are infinitely smaller than others. The fact that certain items refer to the new origin and others to the primary shows how integration is achieved; we are able to use the terms which refer to the primary origin to enable us to recreate the primary equation. I have no doubt that this explanation will eventually find its way into the textbooks and that much of the mystery of the subject will disappear, a great gain to students.

The problem of instantaneous speed takes on a new aspect. How can instantaneous speed be calculated? The answer is by making the body continue its motion at a steady speed for a convenient distance s. If it does this in time t its speed will be s/t , which is the slope of the tangent. But s/t is the same as ds/dt as shown above, and that is why differentiation gives the instantaneous speed. Thus the instantaneous speed at the point in question may be calculated. If the body does one mile in one minute, the instantaneous speed at the selected point is sixty miles per hour. This is the way the calculus really works. Of course one may talk about the small distance traversed in a short time but the calculus really gives the

distance traversed in any time after the speed has been made constant. Once more we get rid of the $\frac{0}{0}$ business about which Whitehead has so much to say.

Some years ago I described in the *Electrician* a machine by which curves might be differentiated and integrated on this principle. It is cheap to make and suitable for flatish curves of large size such as one might get in bridge designs, etc. I have been hoping to see a note some day in the press that the apparatus has been developed abroad.

Now we come to an explanation of a further meaning of $0/0$ which is much discussed in mathematics. What is the value of $(x^2 - 1)/(x - 1)$ when $x = 1$? One may divide out $x - 1$ and find out that the answer is 2, but how can $0/0 = 2$? Some books tell us that $0/0$ is meaningless and there are other explanations. I suggest that the explanation is simple and logical and free from mystery. Write $y = (x^2 - 1)/(x - 1)$ and change it to $y(x - 1) = x^2 - 1$. When $x = 1$, y is blotted out; there is an invisible gap in the curve. Consider the curve $y = x^2 \frac{\cos nx}{\cos x}$ where n is large. If you divide out the $\cos nx$ term you get $y = x^2$ but if you write it $y \cos nx = x^2 \cos nx$, then every time that $\cos nx = 0$, the y is blotted out and the curve consists of a number of separate short lines which butt up against each other with invisible gaps between. You may say in the case of $y = \frac{x^2 - 1}{x - 1}$ that $y = 2$, in the neighbourhood of $x=1$, or that y approximates to 2, or you may say that y would equal 2 at this point if it existed.

It is not difficult to think out ideas which may be useful if put into circulation but it is difficult to get them introduced to the proper quarters. I hope, however, that the above ideas will be duly circulated.

Lathe Work

The Press at Coombelands Ltd., Weybridge, Surrey, have recently published a very useful handbook for the newcomer to the engineering trade entitled *Lathe Work*. It was originally compiled by Messrs. Saunders-Roe Ltd.: the authors are V. T. Stevensons and A. C. McBain, M.A. The book is full of useful information and it is amply illustrated. The prices are: limp bound 1s. 9d.; stiff bound 2s. 3d. per copy. Very generously Messrs. Saunders-Roe have arranged that all royalties from sales go direct to the R.A.F. Benevolent Fund.

Rising Mains in Buildings

By F. CHARLES RAPHAEL, M.I.E.E.,
M.A.Cons.E., F.I.E.S.

IT all depends, as Dr. Joad would say, on what you mean by a building. Different considerations apply to small and large residences, blocks of flats, office buildings and commercial and industrial premises. In small houses, such as will be built in their thousands after the war, there will be no rising mains, strictly speaking; sub-circuits of V.I.R. cable or such efficient substitute as P.V.C. which may find favour owing to there being insufficient supplies of rubber, will be run from a main fuseboard to the various points, and the only main cable beyond the house-service cut-out will be the short connection between this and the fuseboard. Even this may become unnecessary as there is a growing preference for the combination into one unit of the house service cut-out, the meter-board and the consumer's main fuseboard. Recently, many installation engineers have urged the use of a ring-main for all the socket-outlet points, both ends of this terminating on the same way of the fuseboard. This may be considered more or less as a sub-main. Suggestions have been put forward for the use of bare conductors in a plastic casing for this purpose, but it seems more probable that ordinary cable with boxes at suitable points for looping-in or for tee-ing off socket-outlets will be the prevailing practice.

In larger residential property, when one or more sub-fuseboards are required on upper floors, paper-lead cable with simple sealing ends can be more economical than cable in conduit for the rising mains and has the advantage that its current-carrying capacity is greater for the same sectional area of conductor, and that it can be safely overloaded. Under immediate post-war conditions, a demand for a larger number of rising services is bound to arise for the conversion of existing and re-conditioned houses into flats. If the existing service is large enough, the supply authority will probably loop out a rising cable from the existing house-service cut-out, using a separate main fuse and meter for the consumer on the upper floor. Paper-lead cable (post-war conditions will probably permit this to be armoured once more) with simple end-boxes will be the most economical and suitable for this in most cases, but failing that, V.I.R. or P.V.C. cable in screwed conduit can be employed. Sufficient current-carrying capacity must be allowed for a cooker to be installed as well as

provision for lighting and heating load, as each flat will presumably have its own kitchen.

For new blocks of flats there should be consultation with the architect and the landlord at the plan stage, so that provision of the most suitable system of risers can be arranged. It has frequently been said that the principles that should govern rising mains of this character are identical with those of a street distribution network, except that the cables are vertical instead of horizontal. This is not actually the case. A short-circuit or earth fault in the street may involve interruption of supply to consumers until it is cleared, but no appreciable fire-risk, and an overload will do no more than cause undue pressure drop or out-of-balance conditions. Rising mains in buildings should conform with the I.E.E. Regulations for the Electrical Equipment of Buildings which specify maximum current-carrying capacity for conductors lower in most cases than the maximum regarded safe for street mains, for which the tables in the C.R. handbook have always been a useful guide. It should be noted that, as a war-emergency measure, increased ratings above those in the tables of the 11th Edition of the I.E.E. Regulations, are now permitted in the smaller sizes of all classes of cables up to .0045 sq. in. and that the larger V.I.R. cables (from .007 sq. in.) may be loaded at 20 per cent. above the ratings in the I.E.E. tables; but no increase has been made in the I.E.E. ratings of the larger lead-covered cables. In estimating the load, however, account may and should always be taken of diversity factor over the whole building and on each floor. The habits of flat-dwellers differ not only in different districts but in the same building. The peak load will never be as high as the installed load. For instance, it will usually be for short periods only that the full load of a cooker is on, or, if there is thermostatically controlled water heating, that the water-heating maximum will coincide with the cooker peak.

In large blocks of flats, choice will usually be made between paper-lead and bare conductors supported on insulators for the rising mains. For either system, arrangements should be made with the architect for the provision of a duct in a conveniently central position: if bare risers are used, this is absolutely essential. In buildings covering a very large floor area including several independent flats on each floor, two or more sets of rising mains may be an advantage to save heavy horizontal runs. It should be remembered, however, that with two or more separate risers, the diversity factor on each will be less, while, on the other hand, if maximum permissible current densities are likely to be employed, these are less for cables of larger section. The best place for the rising duct

is usually adjoining the lift shaft. Suitable barriers must be provided in the duct to prevent a fire from spreading from floor to floor.

Bare risers on insulators may be either of copper or aluminium and either of circular or flat section. At each floor a fuseboard is provided and suitable clamping connections to tap out to its 'bus bars from the rising conductors. These fuseboards may be of the surface type; or alternatively, an iron-clad flush pattern recessed into the front of the duct makes a very neat job. But in either case V.I.R. tails should not be used, as there should be no combustible material within the duct. An even better arrangement, suitable for taking off large loads, is to arrange for a small chamber leading out of the duct on each floor for the reception of the fuseboard and its connections and this could accommodate a main fuse controlling the whole floor, but provision must then be made for leading in the sub-circuit wiring which will feed the consumers' boards.

If paper-lead risers are used, they may be looped from fuseboard to fuseboard to a certain extent, but for heavy loads it is often preferable to run one set of risers to each floor or to alternate floors or every third floor, with separate main fuses for each riser in the basement switch-room.

In most cases, a 4-wire 3-phase system would be used with connections to the consumers' fuseboards between phase wire and neutral, but in accordance with modern practice there should be no fuses on the neutral so that the consumers' fuseboards would be single-pole only, with a neutral 'bus bar. Whether the loads should be balanced across the phase on each floor will depend on the number of consumers on each to be served: if there are only one or two consumers on each the floors can be balanced against one another.

Each flat would have its own main fuse and meter, so that no meter for the main supply to the building is necessary. The "Landlord's circuit" for lighting the stairs and corridors, serving the lifts, etc., would thus have to be metered independently with separate risers to the floors.

In large office buildings and business premises the conditions as regards rising mains are very similar except that the load cannot be so accurately pre-determined, and if the whole building is occupied by one firm and not sub-let to tenants in groups of offices, etc., a separate landlord's circuit is not necessary. Frequently, however, a separate pilot circuit is required for all-night use to light the stairs independently and to supply pilot lights for the night watchman.

If an under-floor duct system is used for office wiring, arrangements may have to be made for it to be brought right into the floor fuse chamber to facilitate alterations in the floor distribution when different sub-divisions of the floor space are made for new tenants.

Some architects have endeavoured to allocate one rising duct common to the electricity, gas and hot and cold-water supply. Instances have occurred where this has been provided without consultation with the specialists responsible for these services, with the result that each has refused to share it with the other and in consequence it has remained unused. There is no reason why the separate rising ducts should not be adjacent, but they should be separate.

On multi floor school buildings, the load can be pre-determined with considerable accuracy, and paper-lead risers are to be recommended. Provision of a rising casing for these is an advantage, but not an absolute necessity, and in the reconstruction or extension of existing schools no great difficulty occurs in arranging a route for the risers. It is probable that a fair proportion of the new schools to be built will be single-floor buildings, and the distribution from the mains intake to the various fuseboards will be by fairly long cables. If space for ducts is limited, there is no grave objection for ducts under the corridors to be shared between the heating engineer and the electrical engineer, provided the latter uses paper-lead armoured cables properly supported and kept as far away as possible from the hot water pipes, and these pipes are well lagged.

Welding Assists Electrical Development

By C. W. BRETT, M.Inst.W.

Managing Director of Barimar Ltd.

ENGINEERING has advanced so rapidly in many directions that it is virtually impossible to keep in touch with all progress apart from those activities in which one is directly interested.

If matters could be otherwise it is certain that far wider application of new processes and methods would be made. This fact is demonstrated by the spectacular advances that are evident in scientific welding. In the field of repair work particularly, vastly improved technique with effective means for handling difficult jobs, hitherto considered to be impracticable, has opened up resources which, so far, are utilized to nothing like the extent that the opportunities merit.

It is generally realised that welding is the most dependable means for restoring a fractured casting to a condition of soundness, but there are few engineers who appreciate that totally dissimilar metals can be welded together with equal dependability, yet it is a matter that may be of great importance in many branches of electrical engineering.

Research workers devoted a great deal of time and made many thousands of experiments before the welded union of diverse materials became practical on a commercial basis. The chief objective was to widen the scope of general repair work still further. When a method was found for welding cast or malleable iron to steel, it was considered in some quarters that a limit had been reached and that variations in the respective coefficients of expansion of the different metals would bar further progress. This view has since proved to be wrong, for nowadays such divergent materials as aluminium and steel are being welded together with the same success as the more familiar repairs undertaken by scientific welding specialists with similar metals. Tests to destruction, applied by increasing the stress until fracture occurs, invariably causes the weaker of the two parent metals to fail before there is any yield in the area of union, thus proving that a true weld is obtained.

The difficulty experienced at one time in welding copper has now been overcome entirely, but this is a fact not yet realised if one may judge by the unwarranted limitations which some engineers still impute to welding.

To some extent, recent progress can be attributed to the war. Demands have been made upon welding specialists that a few years ago would have been considered impossible to meet. Sometimes, needs have been so urgent that welding alone could save the situation. Often the plant in need of attention has been too bulky or heavy to render transport feasible, in which case welding operators have been despatched to the site with portable equipment. In many instances the work has been done at great personal risk; on other occasions restricted access or danger from fumes has made continuous duty for more than ten minutes a physical impossibility, so that relays of operators have been employed. Whatever the conditions, the results have been permanent, for there is nothing of a temporary nature about a welded repair.

Most of the repairs undertaken on behalf of electrical engineers are those resulting from breakage. Damage to switch box casings and the wide variety of other castings of lighting, power and heating electrical apparatus are repaired quickly and invisibly. Often wear or corrosion creates trouble which would be difficult to correct promptly if replacement parts are awaited, but fortunately there is no

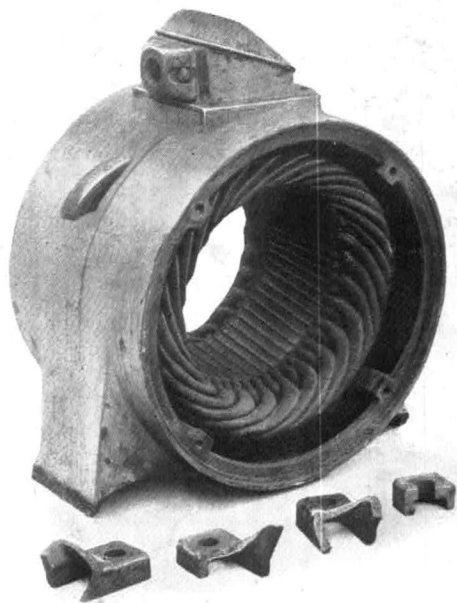


FIG. 1. A.C. Motor Frame broken.

need for this. If welding is applied there is no appreciable delay, the cost is only a small fraction of that of renewal, whilst the re-conditioned part is at least equal to new and often far better, because the conditions of duty can be taken into consideration so that the best possible choice of weld metal can be made with a view to offering increased resistance to any repetition of the trouble.

A point that is sometimes overlooked is the high standard of skill and experience that is essential to trustworthy welding repair work. Versatility on the part of the operator is imperative, for the work undertaken is infinite in variety.

Metal spraying is an off-shoot of welding. It is particularly useful in preventing corrosion. It is done by passing a wire or powder of the metal required through an oxy-acetylene flame. Instantaneously the metal becomes molten when it is forcibly ejected from the "gun," as it is called, and, in the form of tiny particles the coating adheres tenaciously to all except polished surfaces. Strangely this is a cold process and even paper can be coated without risk of scorching. Zinc is often sprayed as a means for preventing corrosion, whilst coatings of aluminium are also valuable in many ways.

Damaged components weighing a few ounces to 10-12 tons are usually sent to the shops of the scientific welding engineer for attention where any machining that may be required subsequent to welding is also undertaken.

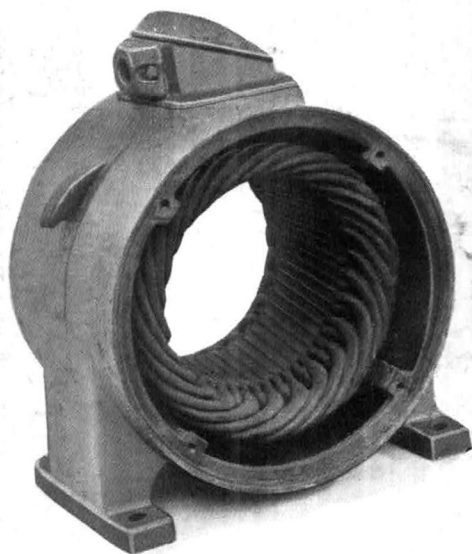


FIG. 2. After repair : Windings not disturbed.

At one time pre-heating was considered to be a necessary preliminary to welding. Sometimes there was objection to this and in any event it was time-wasting. Present methods enable work to be undertaken cold; in fact, provided that there is reasonable accessibility, it is feasible to weld a damaged part without removing it from its normal position, although of course, it must be dismantled if there is any machining to be done.

These are days in which every piece of scrap metal is needed, hence it is wasteful to discard any metal part which can be returned to its original condition of usefulness once more. If this waste is countenanced, an additional burden is added to the nation's resources of labour and material, for it is seldom a short stride from the melting pot to the finished article.

This aspect of welding can be advanced still further. There is a good deal of used plant, particularly that of Continental origin, which is available quite cheaply because replacement parts are difficult or impossible to secure. So long as components are not missing but only damaged, a full measure of efficiency can be re-gained; an actual increase in strength may be imparted if this is necessary, whilst there is no trace of what has been done.

The welding of steel items is largely electrical, but gas welding is more usual although by no means exclusively used upon cast iron. Great strides have been made in controlling heat flow; in fact it is because of this close control that pre-heating is virtually obsolete.

Concluded on page 183

Problem Circle

BY way of a change we present a "square word" puzzle. It will prove not as easy as at first sight. This is it:

Produce a "square word" of 8 or more words. N E S T L E S

An example is given of a 7 letter square word which, according to information received, is the most that has been done. E N T R A N T

Can you beat it? No prize is offered, but the Editor welcomes attempts from readers. S T R A N G E

And here is another diversion requiring no particular mathematical skill: it is just a matter of sorting out the given facts and their implications and making correct deductions to arrive at the answer. T R A I T O R

Three families, each a father, mother and a son, have one saving's box each individual. Fathers collect half-crowns, mothers shillings, and sons pennies. To date, each family has a total of 100 coins = £5. Tommy's mother has more coins in her box than anyone else. Mr. Jones has collected £2 10s. 0d. more than Albert, and Mrs. Smith's box contains 2 coins more than Mr. Brown's. What is Willie's surname and how much has he collected? L A N T E R N

Again, no prize is offered: the solution is given on page 174. E N G O R G E

Problem 297 brought in quite a good response: most of the answers were correct. From the given data an equation of the form $\sin \theta - \theta \cos \theta = \frac{\pi}{2}$ is evolved from which the answer is derived by a curve or trial. It is a long while since we had the pleasure of awarding the prize, according to the rules, to a member of the fair sex. For this problem the prize of 10s. 6d. is awarded to Miss Mary F. Godwin, 9, High Mount Street, Hedsnesford, Staffs. We congratulate her on her effort. The correct answer is $ON = 116$ approx: there is no exact solution. The problem was to find the length (ON), of a chord on a circle of radius of 100 units such that the arc of the circle struck with the chord as radius would bisect the area of the circle of 100 units radius. S T E R N E R

Problem 298 brought in a good number of replies, many of which were correct. The prize of 10s. 6d. goes north again, to Mr. J. M. Holgate, Corporation Electy. Dept., Morecambe, Lancs. The correct solution of this double acrostic by "Pablo" is:—

K no B
N atura L
I nerti A
F oo D
E laps E

Problem 299. Acknowledgments are made to Mr. R. Baldwin for this teaser.

Three children, A, B and C, each have an equal number of uniform bricks. A builds a wall one brick high round a rectangular space and continues to build contiguous brick walls round the first wall, of an ever increasing number of bricks, until all the child's bricks are used up. It has then built an exact number of brick walls. B continues the work of building contiguous walls round those of A and again completes an exact number of walls with the available bricks. Similarly C continues and on completing as many walls as possible, has four bricks left over. What is the minimum number of bricks each child had?

Problem 300, a double acrostic, again comes from our old friend "Pablo."

First made,
Second took.

(Better raid
Children's book).

- (1) This must be said—I can't be dead.
- (2) All roughly I am fashion—ed.
- (3) Puzzle it out—
- (4) Valley about—
- (5) Strenuous match, there's little doubt.

The usual prize of half-a-guinea each is offered for the first correct solution of Problems 299 and 300 to be opened.

Entries should be sent to our Editorial Offices: 51/53 Hatton Garden, London, E.C.1, by 20th November, 1943. The Editor's decision must be accepted as final.

E.A.W. Annual Report

The Director and Secretary, Miss Caroline Haslett, O.B.E., Comp.I.E.E., is to be congratulated on the Eighteenth Annual Report of the Electrical Association for Women. It is a very interesting document revealing the wide scope of the Association's activities.

Housing and kitchen planning and domestic electrical equipment have been closely studied in connection with the E.A.W.'s post-war reconstruction project. The Association's activities in connection with education, women's post-war training and employment, co-operation with the Women's Engineering Society and the International Women's Service Group, and Fuel Economy interests are explained, together with other phases of the Association's interests.

Résumé of Technical Literature

Issued from Henley Research Laboratories

Winding Wire Covering.—H. C. GEE, J. F. COWEN.

(*Elect. Rev.*, Vol. 133/pp. 134—6/30.7.1943).

The outstanding mechanical properties and chemical inertness of Nylon has prompted its evolution as a wire coating material applied from solution, but whilst Nylon coverings were most encouraging in these respects the electrical properties failed to reach the minimum standard required for magnet wires.

Improved electrical properties have, however, been imparted to Nylon without sacrifice of other important properties by the incorporation of thermosetting resins. Modified Nylon coverings have a high space factor and moreover, are completely unaffected by most organic solvents. The covering is, however, softened by alcohols and by phenolic bodies. Impregnating agents having an excess of free formaldehyde or phenol, or having an alcohol solvent should be avoided.

Various tests carried out have shown that thermoplastic flow, ozone resistance, adhesion and abrasion resistance are excellent.

Mechanical Properties of Plastics at Low Temperatures.

(*Plastics*, Vol. 6/pp. 439-442/Dec., 1942).
(*Kunststoffe*, Vol. 32/pp. 141-2/May, 1942).

Article summarises recent investigations on the low temperature properties of plastics with respect to elastic modulus and deformation characteristics.

Lacquering on Insulated Wire and Cable, Parts I and II.—C. A. LITZLER.

(*Wire and W. Prod.*, Vol. 18/pp. 285, 289, 293 302-304/May, 1943).

The operation and design of a cable lacquering plant as developed by the Industrial Oven Engineering Co., Cleveland, Ohio, is described. It has been found that the speed of the wire plus the speed of the air past the wire is one of the determining factors in drying time. Reference is made to work carried out on the pressure method of lacquer application and also to the beneficial effects of wire preheating.

A description of the various means available for handling the wire so as to avoid jerks and whipping is also included.

Stability of Impregnated-Paper Insulation.—J. B. WHITEHEAD.

(*Elect. Engng.*, Vol. 61/pp. 554-5/Nov., 1942).

This short article summarises the results of a series of experiments made to determine the influence of various factors in paper cable design on the dielectric strength. The main conclusions are :—

- (1) Increasing paper density results in decreasing dielectric strength.
- (2) Increasing paper thickness results in decreasing dielectric strength.
- (3) Increasing width of channel causes decreasing dielectric strength, up to widths of about $\frac{1}{8}$ ".
- (4) Failures usually begin in the oil channels.
- (5) Comparative tests on open and closed specimens resulted in no appreciable difference in dielectric strength or life.

These experiments have all been described in greater detail in previous papers.

Tin-Conserving Solders.—G. F. BEARD.

(*Metal Ind.*, Lond., Vol. 62/pp. 375-7/11.6.43.)

The article outlines briefly the principal characteristics of 50/50 tin-lead, cadmium-lead, silver-lead and tin-lead solders.

Paracon—New Synthetic Rubber.

(*India Rubb. World.*, Vol. 108/p. 150/May, 1943).

Paracon is a polyester type of material. In its raw state it is quite plastic and may be worked on ordinary rubber machinery. The oxide pigments are the most satisfactory fillers. Carbon black has an adverse effect on the curing properties and is not advised. Vulcanisation is accomplished without sulphur and accelerators.

The heat resistance of Paracon is claimed to be exceptional. Compounds in service at 150° C. are said to outlast both natural and synthetic rubbers. Oil and petrol resistance are also reported as very good. The material was originally synthesised in the Bell Telephone Laboratories and is now being produced on a semi-commercial scale by the Resinous Products and Chemical Co.

Flexible Trailing and Drill Cables.—W. WATKINS.

(*Min. Elect. Engnr.* Vol. 24/pp. 44-48/June, 1943).

The paper deals with the present design of flexible cables used with coal-cutters, conveyors and drills and discusses the favourable and unfavourable points in their make up.